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BIO-ENGINEERING ASPECTS OF AGRICULTURAL DRAINAGE

SAN JOAQUIN VALLEY, CALIFORNIA

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POSSIBILITY OF REDUCING NITROGEN IN DRAINAGE WATER BY ON FARM PRACTICES

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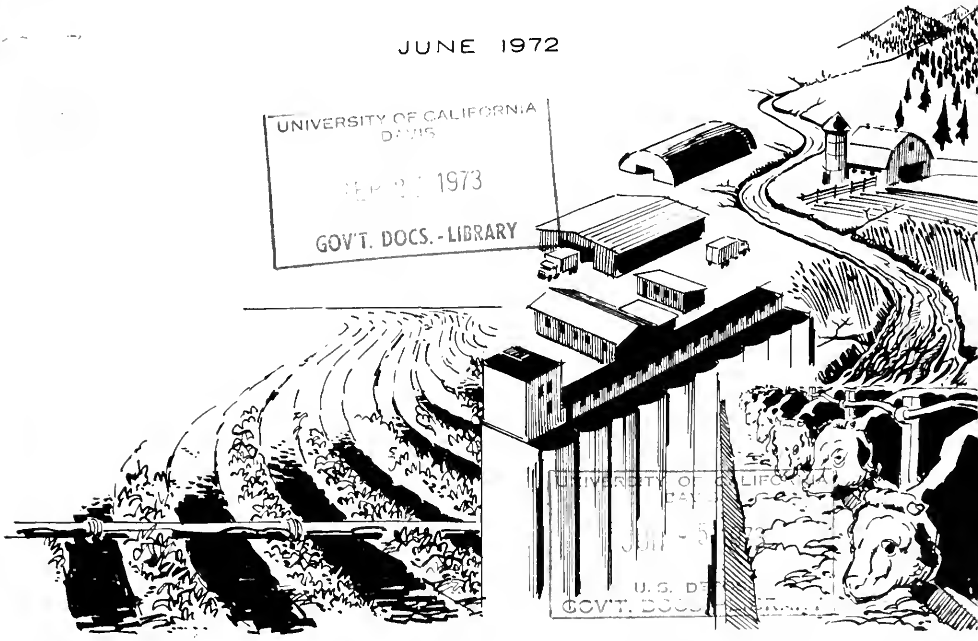

ENVIRONMENTAL PROTECTION AGENCY●RESEARCH AND MONITORING

UNITED STATES BUREAU OF RECLAMATION

BIO-ENGINEERING ASPECTS OF AGRICULTURAL DRAINAGE
SAN JOAQUIN VALLEY, CALIFORNIA

The Bio-Engineering Aspects of Agricultural Drainage reports describe the results of a unique interagency study of the occurrence of nitrogen and nitrogen removal treatment of subsurface agricultural wastewaters of the San Joaquin Valley, California.

The three principal agencies involved in the study are the Water Quality Office of the Environmental Protection Agency, the United States Bureau of Reclamation, and the California Department of Water Resources.

Inquiries pertaining to the Bio-Engineering Aspects of Agricultural Drainage reports should be directed to the author agency, but may be directed to any one of the three principal agencies.

THE REPORTS

It is planned that a series of twelve reports will be issued describing the results of the interagency study.

There will be a summary report covering all phases of the study.

A group of four reports will be prepared on the phase of the study related to predictions of subsurface agricultural wastewater quality--one report by each of the three agencies, and a summary of the three reports.

Another group of four reports will be prepared on the treatment methods studies and on the biostimulatory testing of the treatment plant effluent. There will be three basic reports and a summary of the three reports. This report, "POSSIBILITY OF REDUCING NITROGEN IN DRAINAGE WATER BY ON FARM PRACTICES," is one of the three basic reports of this group.

The other three planned reports will cover (1) techniques to reduce nitrogen during transport or storage, (2) removal of nitrate by an algal system, and (3) desalination of subsurface agricultural wastewaters.

BIO-ENGINEERING ASPECTS OF AGRICULTURAL DRAINAGE
SAN JOAQUIN VALLEY, CALIFORNIA

POSSIBILITY OF REDUCING NITROGEN IN DRAINAGE WATER BY ON FARM PRACTICES

Prepared by the

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REVIEW NOTICE

This report has been reviwed by the Water Quality Office, Environmental Protection Agency and the California Department of Water Resources, and has been approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Water Quality Office, Environmental Protection Agency, or the California Department of Water Resources.

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ABSTRACT

A nitrogen balance study of the San Luis Service Area determined that the average annual nitrogen contributions from all sources other than residual soil nitrogen were approximately equal to the nitrogen removal by crops and volatilization losses. This would indicate that, although in many instances the residual nitrogen would replace some of the contributed nitrogen, especially fertilizers, animal and municipal wastes, the amount of nitrates moved to the drains would be directly proportional to the amounts of soluble, native nitrogen in the soil.

A soil sampling study at several sites throughout the area indicated that there was a wide range in the concentrations of nitrates, ammonia and organic nitrogen in the soils and subsoil. There were extremely high concentrations of nitrates in those soils located on the interfan positions between the larger streams.

Fertilizer studies in lysimeters show that in medium to heavy textured soils under normal irrigation and fertilizer management practices very little nitrogen fertilizer is leached to the drains. Nitrate type fertilizer contributed more nitrogen to the drainage effluent than ammonia and slow release sulfur coated urea fertilizers.

It was concluded that the best possibilities to reduce nitrogen in drains by on farm practices will be to establish Farm Advisory Programs to encourage the most efficient farm management and fertilizer practices and, if found feasible, to design drain systems to promote denitrification and reduce the area swept by the drain flow lines.

BACKGROUND

This report is one of a series which presents the findings of intensive interagency investigations of practical means to control the nitrate concentration in subsurface agricultural waste water prior to its discharge into other water. The primary participants in the program are the Federal Water Quality Administration, the United States Bureau of Reclamation, and the California Department of Water Resources, but several other agencies also are cooperating in the program. These three agencies initiated the program because they are responsible for providing a system for disposing of subsurface agricultural waste water from the San Joaquin Valley of California and protecting water quality in California's water bodies. Other agencies cooperated in the program by providing particular knowledge pertaining to specific parts of the overall task.

The need to ultimately provide subsurface drainage for large areas of agricultural land in the western and southern San Joaquin Valley has been recognized for some time. In 1954, the Bureau of Reclamation included a drain in its feasibility report of the San Luis Unit. In 1957, the California Department of Water Resources initiated an investigation to assess the extent of salinity and high ground water problems and to develop plans for drainage and export facilities. The Burns-Porter Act, in 1960, authorized San Joaquin Valley drainage facilities as a part of the California Water Plan.

The authorizing legislation for the San Luis Unit of the Bureau of Reclamation's Central Valley Project, Public Law 86-488, passed in June 1960, included drainage facilities to serve project lands. This Act required that the Secretary of Interior either provide for constructing the San Luis Drain to the Delta or receive satisfactory assurance that the State of California would provide a master drain for the San Joaquin Valley that would adequately serve the San Luis Unit.

Investigations by the Bureau of Reclamation and the Department of Water Resources revealed that serious drainage problems already exist and that areas requiring subsurface drainage would probably exceed 1,000,000 acres by the year 2020. Disposal of the drainage into the Sacramento-San Joaquin Delta near Antioch, California, was found to be the least costly alternative plan.

Preliminary data indicated the drainage water would be relatively high in nitrogen. The Federal Water Quality Administration conducted a study to determine the effect of discharging such drainage water on the quality of water in the San Francisco Bay and Delta. Upon completion of this study in 1967, the Administration's report concluded that the nitrogen content of untreated drainage waters could have significant adverse effects upon the fish and recreation values of the receiving waters. The report recommended a three-year research program to establish the economic feasibility of nitrate-nitrogen removal.

As a consequence, the three agencies formed the Interagency Agricultural Wastewater Study Group and developed a three-year cooperative research program which assigned specific areas of responsibility to each of the agencies. The scope of the investigation included an inventory of nitrogen conditions in the potential drainage areas, possible control of nitrates at the source, prediction of drainage quality, changes in nitrogen in transit and methods of nitrogen removal from drain waters, including biological-chemical processes and desalination.

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SECTION I

CONCLUSIONS

1. The major source of the nitrogen in the drainage effluent in the San Luis Service Area is the nitrogen that is native to the soils and subsoils.

2. Under normal soil, cropping, irrigation and fertilizer conditions of this area, only a small percentage of the applied fertilizer nitrogen will reach the drainage effluent; however, in a few small areas of light soils, where excessive irrigation water and fertilizers were applied or the fertilizer application is ill-placed and timed, larger amounts of nitrogen may be leached into the drainage water.

3. There will be local areas of high nitrate concentration adjacent to municipal sewage disposal plants and possibly near cattle feed lots.

4. The reduction of the quantity of nitrogen reaching the drains by controls at the source could be implemented by:

   a. An advisory program conducted by the Extension Service and other agencies to encourage:

      (1) the most efficient rate, type, time and method of fertilizer applications.

      (2) irrigation practices to control excess deep percolation of applied water.

      (3) crop and soil management practices to minimize nitrogen losses.

   b. If research studies on the design of drainage systems to reduce nitrogen in drainage effluent prove feasible, systems should be installed to:

      (1) encourage denitrification by maintaining anaerobic conditions with submerged drains.

      (2) reduce the area swept by the drain flow lines by decreasing the depth and spacing of tile lines.

SECTION II

INTRODUCTION

As a result of the application of large quantities of water to relatively slowly permeable stratified soils, the west side of the San Joaquin Valley now has large areas with groundwater at rootzone depths. These areas, requiring drainage to maintain productivity, will increase in size as more water is imported. Wherever subsurface drains have been installed to control this groundwater, the drainage effluent has had high nitrate concentrations. Investigations were conducted to determine the source of this nitrogen, its form and quantity in the soil, its distribution, and whether its entry into the drains can be controlled or limited.

Large quantities of inorganic nitrogen fertilizers are applied annually and the assumption prevails that fertilizer is the major source of nitrates in the drainage water. The study reported herein was designed to evaluate this assumption and to derive, if possible, practical answers regarding the role of on-farm practices in controlling nitrate out-put from the agricultural lands. This portion of the study was confined to the San Luis Service Area, a part of the west side of the San Joaquin Valley comprising about 669,000 acres. The area is centrally located with respect to present and ultimate drainage areas and was judged to be reasonably representative of the major areas contributing to drainage.

This study examines the nitrogen budget and investigates methods for reducing the quantity of nitrates in the drainage effluent by modifications in type or use of fertilizers, farming practices, or drainage techniques. To accomplish these objectives it was necessary to:

1. Identify the major sources of soil or water nitrogen which contribute to the drainage effluent.

2. Determine the quantities of nitrates that these sources contribute to the drainage effluent.

3. Determine if control of nitrates at the source is needed and if so how can it be accomplished.

SECTION III

LITERATURE REVIEW

The source, movement and fate of nitrogen in soils and water have been the subject of many studies. Tisdale and Nelson (1) describe the various biochemical processes of the nitrogen cycle which occur in soils and their relation to soil fertility.

Stout and Burau (2) compared the accumulation of mobile nitrogen in uncultivated fields with heavily irrigated fields in the Grover City-Arroyo Grande Basin. They found that in permeable soils, nitrate concentrations in the range of 100 p.p.m. would accumulate in the water percolating to the groundwater table, whether uncultivated or cultivated, and with or without fertilization. Doneen, (3) in a study of irrigated fields in the Firebaugh area, states that nitrate-nitrogen in the effluent is principally from three sources; (1) soil organic matter; (2) originally in the soil profile or ground water before irrigation, and (3) fertilizers. The losses of nitrates from the soil and groundwater are in three general categories: (1) removed in the harvested crop, (2) by denitrification, and (3) in the drainage water.

Various studies by Terman (4), Martin and Chapman (5), and Harding (6) conclude that if ammonia or urea types of fertilizer are applied to the surface of warm, moist alkaline soils which are present in this area, there will be large losses of the nitrogen by volatilization in the form of NH_3. However, if the fertilizer is placed a few inches below the soil surface either by tillage or by dissolving in the irrigation water the losses can be minimized.

Significant quantities of nitrogen, primarily in the form of NH_3 and NO_3, enter the soil dissolved in the rain waters. Studies by Junge (7), Gambel and Fisher (8) suggest that in the San Luis Area the average concentrations of these ions are about 0.1 mg/l each. They believe the major sources of these N-forms are from the volatilization of the nitrogen from the soil surface or from industrial plants.

Well water will continue to be a major source of irrigation water for the area. The nitrate concentrations for waters from selected wells in the area were measured and are described by a U. S. Geological Survey open file report (9). The nitrate content of these wells ranged from 0 to 98 mg/l with an average of about 2 mg/l. An analysis of the distribution of nitrates in the water strata above the Corcoran formation in the Sierran and Coast Range sediments is presented in a study by the Groundwater Section of the Geology Branch, U.S.B.R. in Sacramento (10). The NO_3 concentration in these strata ranged from less than 1 to more than 542 mg/l. There were higher concentrations in the Coast Range Sediments than in the Sierran and a reduction of concentrations with depth.

Leguminous plants are a source of nitrogen to the soil. Bartholomew and Clark (11) and Erdman (12) found that under normal conditions these plants fix from a few pounds to more than 300 pounds per acre annually. The majority of this nitrogen is used to produce the crop which is harvested and is not returned to the soil.

The waste from animals can make an appreciable contribution to the nitrogen supply of an area, especially when the animals are concentrated in feed or dairy lots. Leohr (13) gives the waste characteristics of various types of livestock and humans. These characteristics include the amount of nutrients and pollutants, and the chemical and biochemical oxygen demand of the waste. He also presents possible methods to treat or dispose of the waste.

The major loss of nitrogen from the soil occurs through the removal of nitrogen by the crops. Morrison's "Feeds and Feeding" (14) lists the percent of nitrogen in the various crops from which the amount of removal can be estimated. The average nitrogen content of the crops grown in this area varies from a high of 5.31 percent for alfalfa seed to a low of .12 percent for vineyards. The major crops, cotton and grain, contain 2.92 and 1.39 percent, respectively.

SECTION IV

METHODS AND PROCEDURES

This section describes the methods and procedures used in the various phases of the nitrogen balance study.

Nitrogen Balance Study

A nitrogen balance study was made of the San Luis Service Area, the boundary of which is delineated in Figure 1. The budget is important in that it is to be used to identify the quantities of nitrogen which might be controlled through modified farm practices.

The nitrogen balance was made by comparing the estimated annual contributions to the crop root zone of the soil with estimated annual losses that could be identified. Because of the many complexities of the system, it is difficult to determine if the quantities of nitrogen measured in the soil are at equilibrium with the contributions and losses; however, available data indicate that near equilibrium exists. No attempt was made to extend the budget through the substrata and groundwater, however, from data in the study it is noted that in some areas the nitrogen increases down to shallow groundwater, but is markedly less in the deep groundwater. Anticipated changes in the nitrogen regime are also discussed in this study.

Sources of Nitrogen Contribution

The major sources of nitrogen, other than the naturally occurring mineral forms in the soils, that contribute to the system are:

1. Nitrogen fertilizers
2. Mineralization of organic nitrogen compounds
3. Irrigation water
4. Stream and flood flows
5. Rainfall
6. Leguminous plants
7. Livestock
8. Municipal and industrial wastes

Many authorities consider non-symbiotic nitrogen fixation to be a contributor; however, very little is known about the quantities supplied under field conditions because they are too small to be measured (15). Therefore, this source was not included in this study.

The methods used to determine the contribution of each category are listed below:

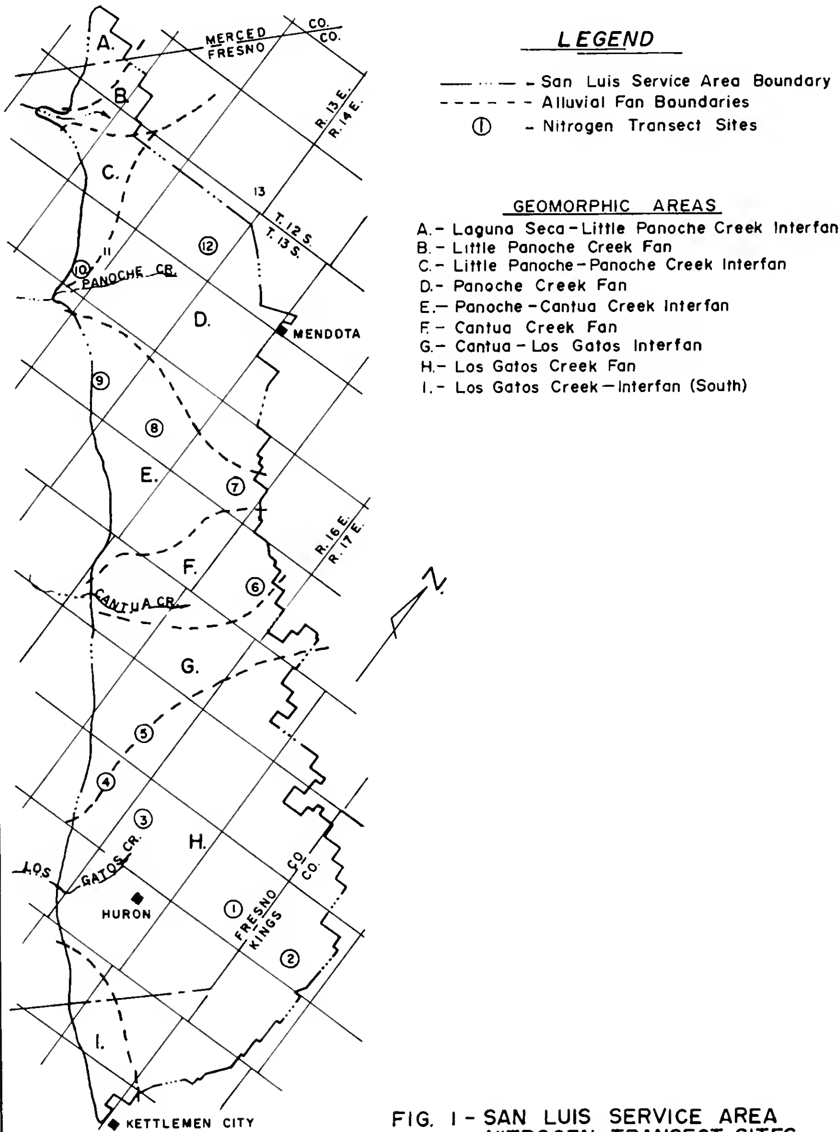

FIG. 1 - SAN LUIS SERVICE AREA
NITROGEN TRANSECT SITES

Nitrogen Fertilizers: The quantity of nitrogen applied in the fertilizer was determined for 1968 and estimated for the ultimate development. This determination was made from the amount applied per acre to each crop and the total number of acres of the various crops. The average application rates were based on Farm Advisors and fertilizer consultants recommendations and field sampling of actual farming practices. The amount applied depended on such factors as soil type, crop history, crop involved and the judgement of the grower.

The acreage devoted to the various crops in 1968 was determined from a crop survey made by the State of California, Department of Water Resources. The projection of the acreage of the various crops under ultimate development conditions was prepared by the U.S. Bureau of Reclamation.

Mineralization of Organic Nitrogen: The mineralization of organic nitrogen compounds is accomplished by various types of micro-organisms. The amount of ammonia and nitrates released by this process depends upon many factors but in general the environmental factors favoring the growth of most agricultural plants are those that also favor the activity of the nitrifying bacteria. The estimates of the quantities of the mineral nitrogen released in these reactions were based on data derived from the literature.

Irrigation Water: The quantity of nitrogen applied by the irrigation water was determined from the amount of water applied and the nitrate concentration of the applied water. The water applied was calculated from the farm irrigation requirement multiplied by the acreage of each crop. The nitrate concentration of the water was determined by calculating the weighted average of the ground-water and the canal water as taken from the chemical analyses of the wells in the area (9) and from State of California, Department of Water Resources data.

Rainfall: The amount of nitrogen supplied by rainfall was determined from the average precipitation in the area as taken from Weather Burau data and the nitrogen concentration in the rain water. This value was derived from work by Junge (7) and Gambel and Fisher (8).

Leguminous Plants: Certain plants in a symbiotic relationship with various species of the Rhizobium bacteria will fix elemental nitrogen. Alfalfa and beans are the legumes grown in this area. The amount of nitrogen fixed by these crops will vary greatly but based on the work of Erdman (12), it is estimated that alfalfa will fix an average of 194 pounds per acre and beans 40 pounds per acre per year. The acreage of these crops was determined from the 1968 crop survey and the estimated ultimate acreage was taken from Bureau of Reclamation studies.

Livestock: The nitrogen contribution by the livestock was taken from the numbers of each type and the waste characteristics of each species. The number of cattle in the area was determined from information supplied by the major feed lots of the area for the 1968 season. The sheep population was estimated from data reported in the 1968 Fresno County Agricultural Report. The number of other livestock in the area is not significant. The waste characteristics of the animals were taken primarily from the work of R. C. Loehr (13).

Municipal and Industrial: This area is sparsely inhabited with the majority of the population centered in several small communities, a number of large labor camps, and the Lemoore Naval Air Station. There are a few agriculture oriented industries in the area. Population figures were estimated from census data supplied by the Fresno County Planning Department. The amount of nitrogen waste contributed by the inhabitants of the area was calculated from data derived from work by Loehr (13). The industrial wastes were determined from field estimates made in the various communities.

Nitrogen Losses from the Soil

The main categories of nitrogen loss in this area are:

1. Removal by crops
2. Volatilization
3. Denitrification
4. Deep percolation and drainage

Wind and water erosion is a major factor in nitrogen removal in some areas, however, in the study area losses by such physical removal are not significant because of relatively level lands, low rainfall, and light winds. The methods used in determining the loss by each category are presented below:

Removal by Crops: The major loss of nitrogen is through removal from the soil by the growing plants. The quantity removed in this way was calculated from the number of acres of each crop grown as determined from the 1968 crop survey and the estimated amount of nitrogen in the various plant materials as determined primarily from Morrison's "Feeds and Feeding" (14).

Volatilization: The loss of nitrogen by volatilization of ammonia and urea type fertilizers was calculated from the amount of those fertilizers applied multiplied by 5 percent, the estimated amount of N volatilized. This value was determined from the laboratory and field studies made on the subject (4)(5) correlated with local soil conditions and farming practices.

Denitrification: Elemental nitrogen gas and/or nitrous oxide are released through denitrification, the biochemical reduction of nitrates under anaerobic conditions. The conditions under which this process occurs are so variable and difficult to measure in the field that no meaningful estimate of the actual values can be made. Therefore, for this study, it is recognized that losses under certain conditions could be significant but no numerical values were assigned.

Deep Percolation and Drainage: The nitrates that are present in the soil system, either native, mineralized, or added, that are not removed by the crop, volatilized, denitrified, or immobilized by conversion to other nitrogen compounds will move with the percolating water where eventually they will either be picked up in the drains or moved into the groundwater. The rate nitrates enter the drains or groundwater for any given period would be the difference between the nitrates contributed and the amount immobilized or removed by processes other than percolation divided by the time required to move the nitrates through the soil profile.

Lysimeter Studies

Lysimeters were operated in Fresno at the Bureau of Reclamation Soils Laboratory to study the movement of nitrogenous fertilizers in soil columns. Eighteen columns made of techite (fiber glass) pipe 15 inches in diameter and 6.7 feet in length were filled with four major soil types developed on the westside of the San Joaquin Valley of California from sediment of the Coast Range Mountains. Five columns were filled with Panoche fine sandy loam, a recent alluvial, light textured, slightly saline soil. Four columns were filled with Panoche silty clay loam and three columns were filled with Panoche clay loam soils similar to the above soils except somewhat finer in texture. Three columns were filled with Oxalis Clay, a fine textured soil, slightly to moderately compacted in the subsoil, and moderately saline. Three columns were filled with Lethent sandy clay loam, a basin rim soil with medium textured surface over a moderately compacted fine textured subsoil with moderate to strong concentration of alkaline and saline salts. The soils were screened, weighed, and placed in the columns and tamped to approximately field density.

The surface and subsurface soil material of the Panoche fine sandy loam, and the Oxalis clay soils were mixed in the lysimeters. The soil material from the Panoche clay loam and the Lethent soils were placed in layered horizons in the same sequence as in the natural condition. A layout of the lysimeters is shown as Figure 2.

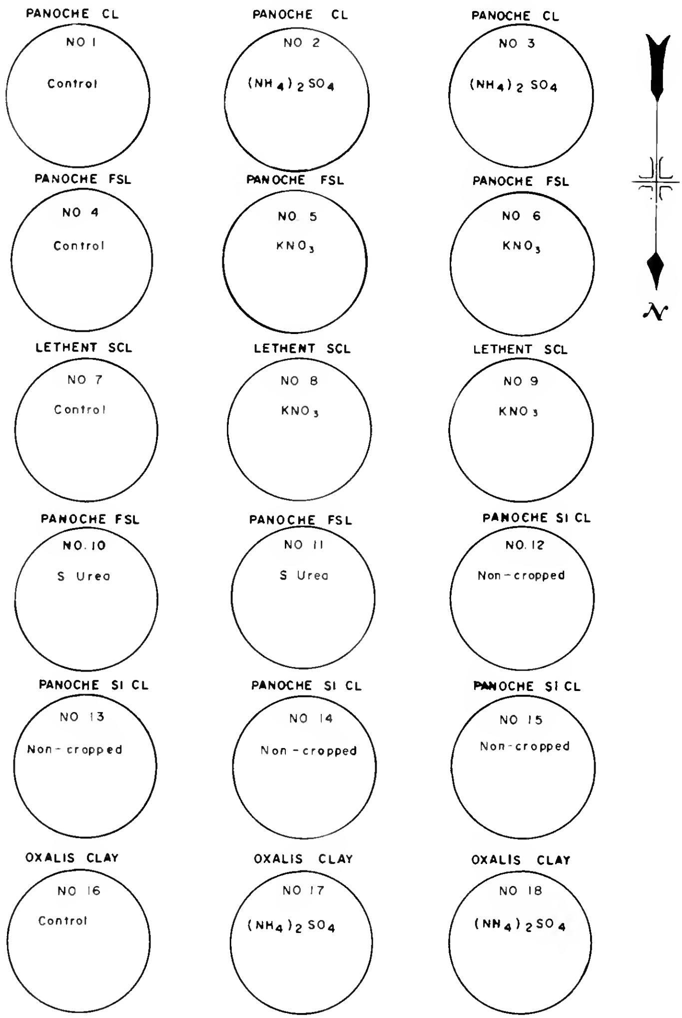

FIG. 2—LAYOUT OF LYSIMETERS—NITROGEN MOVEMENT STUDIES

The lysimeters were instrumented with tensiometers, soil extract suction probes, and soil moisture and temperature cells. These instruments were placed in the soil columns by drilling holes through the sides of the lysimeters and inserting the instruments near the center of the soil columns. Generally four mercury type tensiometers were located in each lysimeter at approximately 18, 30, 42, and 54 inch depths. Three each of the soil extract suction probes and the soil moisture and temperature cells were installed at approximately 12, 24 and 60 inch depths. A typical layout of one lysimeter is shown in Figure 3. When the lysimeters were filled, sufficient water was applied to the columns to bring the soils to field capacity and to start water draining from the lysimeters. After the columns started to drain, water was added in 4-inch increments every two weeks to leach the nitrates to a relatively constant level.

Soil extracts were collected from the suction probes at varying time periods, depending on the needs of the program, by applying approximately 14 pounds of suction with a vacuum pump. Samples of the effluent draining from the bottom of the lysimeters were collected on the same schedule as the soil extracts.

The volumes extracted from the probes and collected in the leachates were recorded. All of the samples were analyzed for nitrates, electrical conductivity and pH. Some of the samples were analyzed for chlorides, ammonia, total nitrogen and percent excess ^{15}N. (an isotope of nitrogen with a mass number of 15)

The leaching program was continued until December 1968. At this time, the nitrate concentrations in most of the lysimeters, although varying with soil type, were reduced to a fairly constant level. Barley was planted in the lysimeters and three different types of nitrogenous fertilizers were applied - $(NH4)_2SO_4$ and KNO_3, both fast nitrogen release types, and sulfur coated urea, a slow nitrogen release type. The fertilizers were applied at a rate equivalent to 100 pounds N per acre or 1250 milligrams of N per lysimeter. The $(NH4)_2SO4$ and the KNO3 fertilizers were eniched with approximately 10 percent ^{15}N and the urea with 28.2 percent ^{15}N. The $(NH4)_2SO4$ was applied to two lysimeters filled with Panoche clay loam and two filled with Oxalis clay. The KNO_3 was applied to two soil columns of Panoche fine sandy loam and two of Lethent sandy clay loam. Sulfur coated urea was applied to two columns of Panoche fine sandy loam. A control to which no fertilizers were applied was maintained for each soil type. Samples from the suction probes and the leachates were collected, frozen and sent to

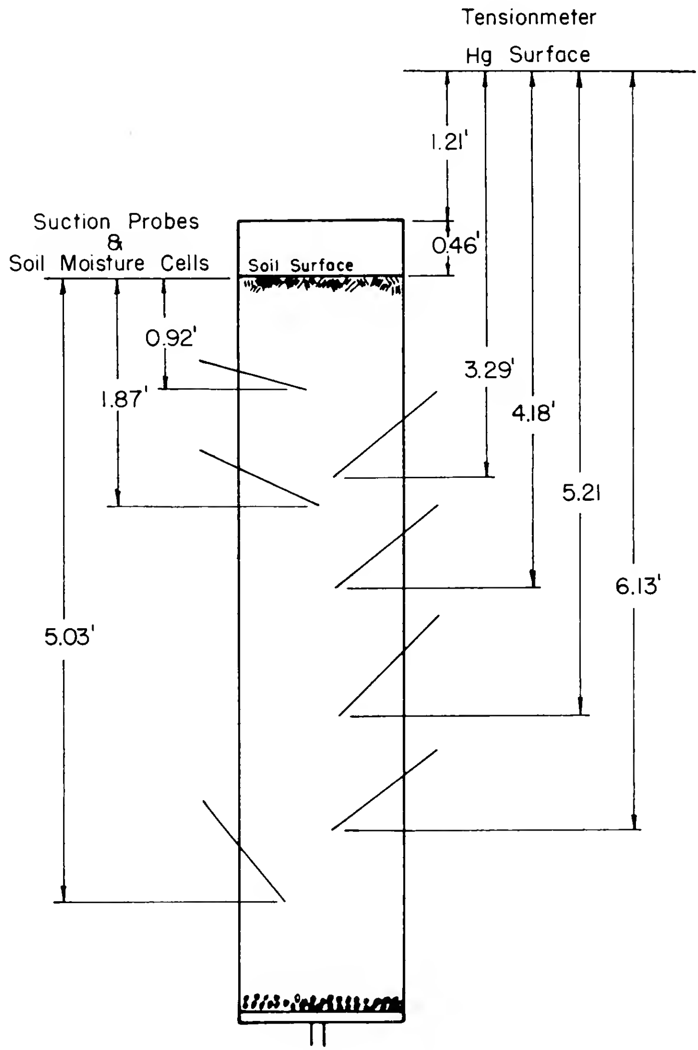

FIG. 3- INSTRUMENT LAYOUT LYSIMETER NO.7

the University of Arizona for analysis of nitrate and atom percent excess ^{15}N, the amount of ^{15}N in excess of that which occurs naturally.

The barley was irrigated at approximately the rate that the farmers of the area use in their normal field operations. The soils were at field capacity when seeded and additional applications of water totaling 19.2 inches were applied during the growing season. The irrigation water applied was obtained from a well at the University of California Westside Field Station near Five Points. This water contained approximately 2 mg/l of NO_3 and 1,000 mg/l of total dissolved solids.

After the barley was harvested in May, eight inches of water were applied to the lysimeters. This amount brought the soils to field capacity and started drainage from the columns. The lysimeters were planted to sorghum without additional fertilization. In addition to the preirrigation of eight inches a subsequent 25.4 inches of water were applied during the growing season. The sorghum was harvested in October 1969.

Grain from the barley and sorghum crops was weighed and analyzed separately from the straw or stover. All plant samples were dried, ground, and analyzed for total nitrogen by standard micro-Kjeldahl procedures. After titration, the ammonia was redistilled and atom percent excess ^{15}N determined.

In addition to those lysimeters used in the plant studies, four columns filled with Panoche silty clay loam were employed to study the movement of nitrogen salts in a non-cropped, moist but unsaturated moisture regime. On January 20, 1969, $Ca(NO_3)_2$ was applied to the soil columns at a rate equivalent to 100 pounds of nitrogen per acre. At the same time, $CaCl_2$ was applied as a source of Cl to serve as a tracer element for the NO_3. Water was applied at the rate of four inches every two weeks. Samples of the soil extract were collected from the suction cups at four depths in the column and the effluent which passed through the column was collected from the bottom of the lysimeter. The samples collected were analyzed for nitrates, pH, electrical conductivity and chlorides. Additional analyses for NH_4, NO_2 and organic N were run on a number of the samples. When it was evident that the first application of salts had moved through the columns NH_4Cl was applied to the columns and the movement of this salt monitored as it moved downward through the soil. The moisture regime was monitored by four mercury type tensiometers in each lysimeter at depths of approximately 12, 24, 36, and 48 inches.

Transect Study

A series of borings was made along several lines transecting the San Luis Service Area generally from east to west. The purpose of

this study was to determine the quantity and distribution of the various nitrogen forms, by area and by depth, and to determine the variability of nitrogen in soils of similar type within small areas.

Thirteen sites were selected along four lines transecting the area. The sites were selected to be representative of the different soil series, physiographic and geomorphic positions. The soil type, physiographic position, and alluvial fan location of each of the sites were as follows:

Hole No.	Soil Type	Physiographic Position	Geomorphic Position
1	Oxalis SiC	Basin Rim	Los Gatos Creek Fan
2	Lethent SiC	Basin Rim	Los Gatos Creek Fan
3	Panoche C L	Recent Alluvial	Los Gatos Creek Fan
4	Panoche SiC	Recent Alluvial	Los Gatos Creek Interfan
5	Oxalis C	Basin Rim	Los Gatos Creek Interfan
6	Lethent C	Basin Rim	Los Gatos Creek Interfan
7	Levis C	Basin Rim	Cantua-Panoche Creek Interfan
8	Oxalis Si C	Basin Rim	Cantua-Panoche Creek Interfan
9	Panoche Si C	Recent Alluvial	Cantua-Panoche Creek Interfan
10	Lost Hills Si C	Older Alluvial	Cantua-Panoche Creek Interfan
11	Panoche C L	Recent Alluvial	Panoche Creek Fan
12	Panoche Si C	Recent Alluvial	Panoche Creek Fan
13	Oxalis C	Basin Rim	Panoche Creek Fan

The locations of the sites are shown on Figure 1. At each of the sites, five holes were bored on a line 50 feet apart. Three holes were drilled to a depth of five feet, one hole to ten feet, and one hole to the water table or 40 feet, whichever occurred first. The soil material in each hole was logged in the field for texture, moisture, permeability, lime, mottling, compaction, structure and temperature.

Two sets of soil samples were collected from each hole. One of the sets was stored in a freezer where it was kept frozen to prevent bacterial activity until the laboratory analyses for the various nitrogen constituents could be made. The other set was delivered to the Regional Soils Laboratory where determinations were made for calcium, magnesium, sodium, carbonates, bicarbonates, sulphates, chlorides, boron, gypsum, lime, pH, saturation percentage, cation exchange capacity, exchangeable sodium percentage and total dissolved solids. Analytical methods for these tests were based on the

Bureau of Reclamation laboratory instructions. (15)

Nitrogen analyses were made for nitrates, ammonia and total organic nitrogen. The nitrates were determined by the specific ion meter, ammonia by distillation and titrating with H_2SO_4 and the total organic nitrogen by the standard micro-Kjeldahl procedure.

Infiltration rate and hydraulic conductivity were determined at the site. The bulk density and porosity were calculated from core samples taken with a split ring density sampler. The infiltration rates were by means of a constant head, double ring infiltrometer. The hydraulic conductivities were determined by the auger hole and shallow well pump-in methods.

A statistical analysis was made of the nitrates, ammonia, and organic nitrogen data to determine the variability of these various constituents within a small area of a similar soil type. The arithmetic average, the standard deviation of the mean and the standard error of the mean were calculated for the data from the upper five feet of the thirteen sites.

The mineral analyses and the tests for the soil physical properties were primarily made to obtain basic data for a prediction model study.

Nitrate Concentrations in the Groundwater

Studies of the nitrate concentration in the groundwater of the area have been made by various agencies. Included in these studies are work by the U. S. Bureau of Reclamation, U. S. Geological Survey, and State of California, Department of Water Resources. The Bureau of Reclamation, California Department of Water Resources and Westlands Water District entered into a cooperative agreement with the U. S. Geological Survey to collect and make chemical analyses of wells in the Dos Palos-Kettleman City area. Between July 15 and September 20, 1968, water samples were collected from 361 wells in the area. The analyses of the samples provided the majority of the data for this study. These analyses, along with the descriptive well data and well location are presented in the U. S. Geological Survey open file report. (9) These data were supplemented with an additional 180 samples collected and analyzed by the Bureau of Reclamation's Fresno office.

Employing data from the wells and the U. S. B. R. geohydrologic test holes nitrate in parts per million was plotted above the Corcoran Clay by depth of well, geomorphic area and by the Sierra or Coast Range sediments. The arithmetic mean and standard deviation was computed by well depth intervals 0-50, 50-150, 150-300, 300-600 and 600-800 feet, on the analyses of nitrates in wells above the Corcoran Clay. Where the number of samples in any interval was less than thirty, the standard deviation was computed from the mean

using one sample less (N-1) than the number used to obtain the arithmetic mean (N).

SECTION V

Results and Discussion

This section discusses the results and findings of the several field and lysimeter investigations on nitrogen balance, residual nitrogen in field soils and the movement of applied fertilizer nitrogen.

Nitrogen Budget

This nitrogen balance study was based on average soil, farming, and irrigation conditions in the area. However, it should be recognized that because of the large size and variable conditions of the area many of the soils will deviate appreciably from the norm, therefore, there will be local areas that will vary significantly from the average values presented here. Precise measurements cannot be obtained under ordinary field conditions, nevertheless these data do supply information that is sufficiently quantitative to show the magnitude of the main soil nitrogen losses and gains.

GENERAL

The nitrogen cycle consists of a series of continuous processes involving the plants, animals and micro-organisms of the soil and air through which the elemental nitrogen moves in the eco-system. The processes involved as they effect the appearance of nitrogen in the drainage water is the concern of this study. Knowledge of the processes in the nitrogen cycle is essential to understanding and dealing with nitrogen in the drainage effluent.

The ultimate source of nitrogen is the inert gas N_2, which constitutes about 78 percent of the earth's atmosphere. In its elemental form it is useless to higher plants therefore it must be converted to usable forms. Although it may be recycled and delivered in many forms, the basic processes by which nitrogen is converted to usable forms and gains entrance to the soils are:

1. Fixation by Rhizobia and other micro-organisms which live symbiotically on the roots of legumes and certain non-leguminous plants.

2. Fixation by free-living soil micro-organisms and perhaps by organisms living on the leaves of tropical plants.

3. Fixation as one of the oxides of nitrogen by atmospheric electrical discharges.

4. Conversion to ammonia, nitrate, urea by any of the various industrial processes for the manufacture of synthetic nitrogen fertilizers.

Plants adsorb most of their nitrogen as NO_3 or NH_4 which in the growth process of the plant are converted to an organic form. Much of this organic nitrogen is reincorporated into the soil by plowing the plant material back into the soil or through the application of animal manures to the soil. These organic forms of soil nitrogen occur as consolidated amino acids or proteins, free amino acids, amino sugars and other complex, generally unidentified compounds. These compounds decompose at various rates ranging from fresh crop residues that are subject to fairly rapid decomposition to lignins which are very resistant to decomposition.

Mineralization is the process by which organic nitrogen is converted to inorganic or mineral nitrogen compounds. Mineralization, through the effect of various types of micro-organisms essentially takes place in three step-by-step reactions: aminization, ammonification and nitrification. These steps are represented schematically by the following formula:

Aminization: Proteins $\rightarrow$ $R\text{-}NH_2 + CO_2$ + energy + other products
Ammonification: $R\text{-}NH_2 + HOH \rightarrow NH_4^+ + \bar{R} + OH$ + energy
Nitrification: $2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+$
$2NO_2 + O_2 \rightarrow 2NO_3$

These reactions will go to completion only if several environmental factors are favorable. Generally, these are 1) adequate supply of ammonium ion, 2) adequate population of nitrifying organisms, 3) adequate aeration, 4) favorable soil moisture and temperature conditions. The most favorable conditions for these reactions to take place occur in the plow zone of moist soils after they have been disturbed and aerated by cultivation.

Nitrates and ammonium are the main mineral nitrogen forms that exist in the soil. The nature of NH_4 permits adsorption and retention by soil collodial material, therefore, it is generally not subject to removal by leaching waters. Nitrate nitrogen is very mobile in some soils and within limits moves with the soil water, therefore, under conditions of excess irrigation or rainfall, nitrates can be leached through the soils and will be concentrated in the subsoils or the groundwater.

As there are processes for the accumulation of nitrogen in the soils, there are processes by which it is lost other than by leaching and crop removal. These losses occur when nitrogen gas, nitrous oxide or ammonia are released because of certain biological and chemical reactions taking place on or in the soils. The three primary processes which cause these losses are:

1. Denitrification: The biochemical reduction of nitrates under anaerobic conditions.

2. Chemical reactions involving nitrates under aerobic conditions.

3. Volatilization of ammonia gas from the surface of alkaline soils.

Although there are conflicting data and opinions, most soil scientists believe that an appreciable amount of applied nitrogen is lost in gaseous forms to the atmosphere. Biological denitrification is considered to be one of the more important processes accounting for these losses and nitrogen, N_2, is believed to be the principle gas produced. Where nitrate occurs in zones of poor aeration, significant quantities of nitrogen can be lost by this process. Nitrogen balance studies have shown mineral nitrogen losses of about 20 percent with cropping and 10 percent with fallow (16).

Normally, ammonia losses resulting from surface volatilization can be prevented or reduced greatly by placing the nitrogen fertilizers several inches below the soil surface.

Nitrogen Contributions

The major sources of nitrogen, not considering that native to the soils are:

Fertilizers

This is an intensively farmed area and to gain maximum yields large amounts of nitrogenous fertilizers are applied. These fertilizers may be classified broadly as either "natural organic" or "chemical." Today in terms of tonnage consumed, chemical sources of nitrogen are by far the most important of the fertilizer nitrogen compounds. Most of the chemical fertilizers applied in this area are ammonia derivatives. Information supplied by local dealers indicates that the amounts of the various types of fertilizers sold in the area were distributed approximately as follows:

	Percent
Ammonia (all forms)	63
Ammonium Sulfate	16
Urea	9
Urea - ammonium compounds	6
Other solids (ammonium nitrate, calcium nitrate, ammonium phosphate)	6

The amount of nitrogen applied to the study area in 1968 based on the acreage and the estimated application rate of each crop is presented in Table 1. The total nitrogen applied was calculated to be 20,210 tons placed on 669,160 gross acres of which 556,875 acres were cropped. This is equivalent to an average application of 73 pounds per productive acre or 64 pounds per gross acre.

Irrigation Water

Irrigation water is supplied to the area from deep wells, the

TABLE 1

Nitrogen Contributed by Fertilizer 1968
San Luis Service Area

Crop	Acres	Nitrogen Applied lbs. per Acre	Nitrogen Applied Total Tons
Cotton	51,119	110	2,810
Cotton (50% ground cover)	48,975	55	1,350
Cotton (70% ground cover)	44,300	77	1,700
Grain	230,832	70	8,080
Sugar Beets	2,661	100	130
Sorghum	3,094	130	200
Safflower	53,440	80	2,140
Field Corn	749	200	70
Misc. Field Crop	492	100	20
Dry Beans	439	0	-
Tomatoes	23,890	100	1,200
Melons	26,314	100	1,320
Lettuce	662	150	50
Carrots	124	120	10
Misc. Truck Crops	1,063	150	80
Alfalfa & Pasture	6,348	40	130
Alfalfa Seed	55,581	20	560
Rice	825	80	30
Deciduous Fruits & Nuts	5,348	120	320
Vineyards	620	45	10
Total Cropped Area	556,875	73	20,210
Non Cropped Area	112,285	0	0
Total	669,160	64	20,210

San Luis Canal and the Delta-Mendota Canal. The relative amounts of nitrogen contributed from these sources are listed in the following paragraphs.

Wells

Prior to the importation of surface water from the San Luis Project, this area was irrigated entirely by water pumped from deep wells. In the future there will continue to be pumping from wells although at a reduced rate. In 1968 it was estimated that about 900,450 acre-feet were supplied from wells. Under ultimate development and a complete distribution syste, it is estimated that 460,000 acre-feet, the annual "safe yield", will be pumped each year.

The nitrate content, the only significant nitrogen form present, was determined for water samples taken from 360 representative irrigation wells which pump from depths of 200 to 3,000 feet. The nitrate -N concentration of these wells ranged from 0 to 10 mg/l

with the average about 0.5 mg/l. In 1968 the nitrogen contributed by well water totaled 610 tons or 1.8 pounds per acre. If it is assumed that the nitrogen content will not vary significantly in the future, the 460,000 acre-feet that will be pumped under ultimate conditions will contribute 310 tons of nitrogen annually. This quantity is equivalent to about 0.9 pounds per acre.

A summary of the contribution of nitrogen from the wells is included in Table 2.

TABLE 2

Total Nitrogen Contributions from Irrigation Water
1968 and Ultimate
San Luis Service Area

Source	Deliveries		Total Nitrogen					
	1968	Ultimate	1968			Ultimate		
	AF	AF	mg/l	lbs/ac	tons	mg/l	lbs/ac	tons
Wells	900,450	460,000	0.5	1.8	610	0.5	0.9	310
Canals	195,600	1,240,000	0.8	0.6	210	0.8	4.0	1,350
Totals	1,096,050	1,700,000		2.4	820		4.9	1,660

Canal Water

The surface deliveries to the area are primarily from the San Luis Canal with smaller amounts from the Delta-Mendota Canal. The source of water for both canals is the San Joaquin-Sacramento River Delta near Tracy. There will be no significant differences in the nitrogen content between the two canals, therefore, the deliveries from both are combined for this study. During the first two years of operation of the San Luis Canal, the weighted average of total N in the water was 0.8 mg/l. This includes about 0.4 mg/l of NO_3-N, 0.1 mg/l of NH_3-N and 0.3 mg/l of organic N. At this rate the total nitrogen contribution to the area in 1968 by the 195,600 acre-feet of canal diversions was 210 tons or an average of 0.6 pounds per acre. Under ultimate development, about 1,240,000 acre-feet will be delivered annually to the service area from the two canals. This quantity of water, assuming the N content remains constant, will add 1,350 tons or 4.0 pounds per acre of nitrogen to the area. The total quantity of N contributed by the irrigation water was 2.4 pounds per acre in 1968 and will rise to 4.9 pounds per acre under ultimate development. A summary of the contribution of nitrogen by canal diversions and groundwater pumpage is in Table 2.

Stream and Flood Flow

The several intermittent streams that flow into the area are a source of nitrogen. These streams originate in the Coast Range Mountains to the west and flow for only short periods in the winter

and spring following the more intense storms over their watersheds. For planning purposes these streams are placed into four groups which include a major stream and several lesser ones. They are, from north to south, the Little Panoche group, Panoche group, Cantua group and the Los Gatos group. The Ground water Section of the Geology Branch of the Bureau of Reclamation at Sacramento has calculated from the historical records the average flow contribution of each of these groups. The nitrogen content of the streams of the various groups was based on tests made by U.S.B.R. Fresno Field Division personnel. Table 3 is a summary of these values.

TABLE 3

Average Annual Nitrogen Contribution by Local Streams
San Luis Service Area

Stream	Quantity AF	N Content PPM	Total N tons	lbs/ac
Los Gatos Group	2,000	0.5	1.3	
Cantua Group	9,000	0.6	7.3	
Panoche Group	14,000	0.5	9.5	
Little Panoche Group	7,000	0.5	4.7	
	32,000		22.8	.07

The 22.8 tons calculated for the area of 669,160 acres would be equivalent to less than 0.1 pounds per acre. Although a sizeable amount it is not significant in the total budget.

Leguminous Plants

For many centuries the use of leguminous crops has been one of the principal means of supplying nitrogen to the soil. In this process various strains of the Rhizobial bacteria growing in a symbiotic relationship with a host plant will fix atmospheric nitrogen in nodules on the roots of the plant. The amount of nitrogen fixed by this process will vary with the type of crop, soil, climate and moisture conditions.

Historically, leguminous native plants were the main contributors of this type of nitrogen in the area, however, with the intensive cultivation of the area most of the native plants have been removed. In their place, a number of cultivated legumes are grown. The largest acreage by far of leguminous crops is in alfalfa. Beans, the only other legume, are a relatively small acreage. Alfalfa seed, which fixes less nitrogen than alfalfa hay, is the major alfalfa crop grown in the area. The weighted average of the nitrogen fixation in this area by the alfalfa seed and hay crops is estimated at 145 pounds per acre. There were 61,929 acres of alfalfa seed and hay grown in the area in 1968. This acreage at the estimated rate of fixation would contribute about 4,500 tons of nitrogen to the area.

The estimated amount of fixation by beans is about 40 pounds per acre. At this rate, the 439 acres of beans grown would contribute about 10 tons of nitrogen.

The total quantity of nitrogen fixed by leguminous crops in 1968 was about 4,510 tons or 13.7 pounds per gross acre. A summary of the nitrogen contribution by legumes is in Table 4.

TABLE 4

Nitrogen Contribution from Legiminous Plants - 1968
San Luis Service Area

Crop	Acres	N/Acre lbs	Total N tons	Ave/Acre (1) lbs
Alfalfa	61,929	194	4,500	13.6
Beans	439	40	10	0.1
			4,510	13.7

(1) Based on gross acreage of service area

Rainfall

Nitrogen compounds are present in the atmosphere and are returned to the earth in rainfall. This nitrogen is mainly in the form of ammonia and nitrate with lesser amounts of nitrite, nitrous oxide, and organic forms. The presence of NO_3 has been attributed to its formation during atmospheric electrical discharges but recent studies suggest that only about 10 to 20 percent of the NO_3 in rainfall is from this source (8). The remainder is thought to come from industrial waste gases or from nitrogenous gases that escape the soil.

The amount of nitrogen that is returned to the soil in this manner has been studied by a number of authors (7) (8). The estimated concentrations for this area are approximately 0.1 part per million of NO_3-N. The average rainfall is about 6.6 inches per year.

The nitrogen contributed to the soil by the rainfall each year would total 100 tons or 0.3 pounds per acre.

Livestock

The livestock population of the area in 1968 was estimated at 37,000 beef cattle and 135,000 sheep. The cattle were concentrated in three feed lots. The sheep graze in the area for about half the year during the fall and winter, and then are moved to higher lands outside the district. There are no appreciable numbers of other types of livestock within the area.

The amount of waste nitrogen contributed by these animals was based on the calculated daily waste excreted by the animals times the number of days fed or pastured in the area. The beef cattle contributed a total of 1,890 tons or based on the gross area, 5.7 pounds per acre. Although some of the manure is removed from the feed lots and spread on other lands, much N will be concentrated in the soils below and immediately adjacent to the feed lots. The sheep are grazed over a relatively large acreage, as a result their waste nitrogen will be distributed fairly evenly over the area. The total N contributed by the sheep was 910 tons or 2.7 pounds per gross acre. The total for all the animals would be 2,800 tons or 8.4 pounds per acre. A summary of the contribution by livestock is in Table 5.

TABLE 5

Nitrogen Contribution for Animals - 1968
San Luis Service Area

Animal	Number	Nitrogen lbs/day/animal	Tons/yr	lbs/AC
Beef Cattle	37,000	.28(2)	1,890	5.7
Sheep	135,300(1)	.09(3)	910	2.7
			2,800	8.4

(1) 150 days/year pastured in area
(2) 9 lbs dry manure/day @ 3.10% N
(3) 1.64 lbs dry manure/day @ 5.4% N

Municipal and Industrial

This is primarily a rural area of relatively large farm operations. Other than the Lemoore Naval Air Station, the largest single employer in the district, the population is concentrated in a few small towns and several large farm labor camps. The industries are limited to a few agriculture related enterprises such as farm equipment dealers, machine shops, trucking firms, and fruit and vegetable packing plants.

The 1960 population as estimated from data supplied by Fresno County Planning Office was 16,450 people and the 1968 population 17,400. These population figures include the Lemoore Naval Air Base and the towns of Mendota, Huron and Five Points. In the work by R. C. Loeher (13) it is estimated that the nitrogen contribution of domestic waste is between 8 - 12 pounds per year per capita. If it is assumed that the average would be 10 pounds per capita the

17,400 people would contribute 87 tons or about .3 pounds per gross acre. This nitrogen is not spread uniformly over the area but it is concentrated in relatively small areas at the disposal plants of the towns and camps. The overall area covered by these population centers is probably not greater than 3,300 acres. If the total quantity of nitrogen waste is prorated to this acreage, the average would be about 53 pounds per acre. It is obvious from this that adjacent to the sewage disposal areas there can be relatively high concentrations of nitrates introduced into the soils although the overall total is small.

Nitrogen Losses

The main causes of the loss of nitrogen from the soil are removal by crops, volatilization of nitrogen fertilizers and denitrification.

Removal by Crops

The major medium of nitrogen removal is through its uptake by the crop and its ultimate removal by harvesting. The quantity of nitrogen removed by this means was determined from the number of acres of each crop as measured by the 1968 crop survey, the estimated crop yields and the nitrogen content of the crop material. These latter values were determined in part from Morrison's "Feed and Feeding" (14). The amount removed was broken down into the materials which are removed from the area and the plant residue that is normally returned to the soil. At least a part of the nitrogen in this latter material will again become available for plant growth through mineralization Although the amount of nitrogen removed by the various crops will vary, depending upon such factors as yield levels, nutrient supply in the soil, fertilizer applied and management practices, representative nitrogen uptake data for the various crops in this area for 1968 are presented in Table 6.

The amount removed ranged from about 322 pounds in alfalfa hay to 37 pounds in beans. The average of all the crops is 89 pounds per acre. This relatively low rate is due primarily to the high percentage of the area planted to barley which has a relatively low utilization rate.

Volatilization of Ammonia Fertilizers

Ammonium salts when applied to an alkaline soil will react to form ammonia gas which if unconfined will be released to the air. The rate of this reaction will vary greatly with soil condition, pH, temperature, moisture content and depth of placement. Studies (4) (6) have shown that when ammonium salts or ammonia gas are placed on the soil surface more than 40 percent of the material can be lost to volatilization, however, if it is placed several inches below the ground surface essentially none of the ammonia is lost. In this area although there are small amounts of the fertilizer applied

TABLE 6

Removal of Nitrogen by Harvested Crop - 1968 - San Luis Service Area

Crop	Acres	Seed, Fruit or Fiber Crop Material Removed Yield				Leaves, Stock or Stover Crop Material Returned Yield			Total	
			Nitrogen % N	Nitrogen lbs/Ac.	Nitrogen Tons		Nitrogen % N	Nitrogen lbs/Ac.	Nitrogen Tons	lbs/Ac.	Tons
Cotton	144,393	1.77 bales	2.92	67	4,840	15 cwt	1.80	27	1,950	94	6,790
Grain	230,832	1.7 tons	1.39	47	5,425	34 cwt	.59	20	2,310	67	7,735
Sugar Beets	2,661	23.0 tons	.22	101	135	150 cwt	.43	64	85	165	2,205
Sorghum	3,094	2.0 tons	1.81	72	110	48 cwt	.51	24	40	96	150
Safflower	53,400	1.1 ton	2.61	57	1,535	26 cwt	.94	24	650	81	2,185
Field Corn	749	2.8 ton	1.34	75	30	67 cwt	.94	63	25	138	55
Field Crops	492	2.0 ton	1.60	64	15	48 cwt	.51	24	5	88	20
Dry Beans	439	760 lbs.	3.66	28	5	9 cwt	.98	9		37	5
Tomatoes	23,890	28 ton	.14	78	935	370 cwt	.14	52	620	230	1,555
Melons	26,314	8 ton	.50	80	1,050	110 cwt	.11	12	155	92	1,205
Truck Crops	1,849	10 ton	.45	90	85	132 cwt	.30	40	35	130	120
Alfalfa Seed	55,581	600 lbs.	5.31	32	880	40 cwt	2.30	92	2,560	124	4,320
Alfalfa & Pasture	6,348	7 ton	2.30	322	1,020	--	--	--	--	322	1,020
Rice	825	2.7 tons	1.26	68	30	54 cwt	.62	33	15	101	45
Nuts	5,348	1000 lbs.	3.98	40	105	180 cwt	.22	40	105	80	210
Vineyards	620	9 ton	.12	22	5	180 cwt	.18	32	10	54	15
Total	556,875			58	16,205			31	8,565	89	25,650

by airplanes, in the water or by broadcast methods the great bulk of it is drilled to several inches below the soil surface. Under these conditions it is estimated that not more than 5 percent of the fertilizer applied is lost.

Approximately 95 percent of 19,200 tons of the fertilizer applied to the area in 1968 was in the ammonia or urea form which is subject to volatilization. If 5 percent of this amount is lost, it would be equivalent to 960 tons or about 3 pounds per gross acre.

Denitrification

Studies have shown that there are losses of nitrogen from soil by denitrification, the biochemical reduction of nitrates under anaerobic conditions (17)(18). In calcareous soils such as are present in this area the loss will primarily be in the form of nitrogen gas. Water logging with its resulting exclusion of oxygen induces denitrification, therefore, in the areas of high water table and in the presence of organic carbon there will be significant losses through this process. Lysimeter studies indicate that under optimum conditions almost 100 percent of the nitrate -N present can be lost through denitrification. The specific quantity of nitrogen lost in the field by this method in this area has been impossible to measure therefore any attempt at this time to put a numerical value on denitrification losses would be meaningless.

Nitrogen Budget Summary

A summary of the quantity of nitrogen contributed and removed from the soil by the various processes is in Table 7. This summary indicates annual nitrogen losses, without attributing any value to denitrification, are slightly greater than the total contributions. Considering the accuracy of the measurements, for all practical purposes there are probably no significant differences between the two.

The total nitrogen removed by the plant from the soil system, including that portion in the plant material that may be returned to the soil, was included as a nitrogen loss item. Although some of this is returned to the soil, it is in an organic form which must be mineralized before it can be utilized by the plant or leached by the percolating waters.

These values are based on an even distribution of nitrogen over the entire acreage, however, in fact, this would not be true. Also the native nitrates and the organic nitrogen that is mineralized are not included in the balance study. Although the quantity of nitrogen moved through the soils to the drains will be roughly equivalent to the contribution from native nitrates and the mineralized organic nitrogen, under actual field conditions these natural nitrogen sources will replace some of the other types in the plant's nitrogen use. Therefore, a part of the nitrogen that is leached to the drain will come

TABLE 7

Nitrogen Budget 1968 - San Luis Service Area

Sources	Nitrogen
Nitrogen Contributions	lbs./ac.
Fertilizer	64.0
Irrigation Water	2.4
Stream Flow	0.1
Rainfall	0.3
Leguminous Plants	13.7
Livestock	8.4
Municipal & Industrial Waste	0.3
	89.2
Losses	
Crop Harvest	89.0
Volatilization	3.0
Denitrification	----
	92.0

from the applied sources, principally from the fertilizer. The amount of fertilizer leached will depend upon many factors, including the type and amount of fertilizer, when and how applied, the crop and root pattern, method and amount of irrigation, and the soil type.

Transect Study

The objectives of the transect study were to determine the quantities and the distribution of the various nitrogen forms, both with depth and areawise and to determine the deviations in soils of similar type within small areas.

Nitrogen in the Soil

The average content of NO_3-N, NH_3-N and organic N in parts per million and the pounds per acre foot for each foot increment were determined from 1:1 soil-water extracts. The quantities of the first five foot increments of each site are listed in Table 8.

The data indicate that the total nitrogen in the top five feet of soil at the various sites ranged from a low of 4321 pounds per acre at site 7, a Levis soil, to a high of 8849 pounds per acre at site 12, a Panoche soil. Of this quantity, the greatest portion by far was the organic nitrogen. The amount in this form ranged from 4140

TABLE 8

Quantities of Various Forms of Nitrogen at Transect Sites as Determined from 1:1 Soil-Water Extracts

Depth	NO_3-N		NH_3-N		Organic N		Total N
Ft	PPM	lbs/AF	PPM	lbs/AF	PPM	lbs/AF	lbs/AF
Site #1 T19S R18E S 23 - Oxalis Soil							
0-1	3.4	12	6	20	520	1872	1904
1-2	18.5	67	3	12	405	1458	1537
2-3	7.9	28	3	10	306	1102	1140
3-4	4.3	15	3	12	213	767	794
4-5	12.6	45	4	15	259	932	992
		167		69		6131	6367
Site #2 T19 R19 S27 - Lethent Soil							
0-1	1.6	6	5	18	633	2279	2303
1-2	4.1	15	2	7	282	1015	1037
2-3	1.4	5	2	7	229	824	836
3-4	1.4	5	1	4	222	799	804
4-5	1.4	5	2	7	222	799	807
		36		43		5716	5787
Site #3 T19 R17 S20 - Panoche Soil							
0-1	3.2	12	6	22	350	1260	1294
1-2	2.3	8	5	18	380	1368	1394
2-3	0.9	3	4	14	224	806	823
3-4	1.1	4	3	11	273	983	998
4-5	1.4	5	3	11	280	1008	1024
		32		76		5425	5533
Site #4 T19 R16 S15 - Panoche Soil							
0-1	11.5	41	4	14	491	1768	1823
1-2	12.5	45	3	11	459	1652	1708
2-3	12.9	46	2	7	315	1134	1187
3-4	8.8	32	3	11	278	1001	1044
4-5	9.7	35	3	11	246	886	932
		199		54		6441	6694

TABLE 8 (Cont.)

Depth	NO_3-N		NH_3-N		Organic N		Total N
Ft	PPM	lbs/AF	PPM	lbs/AF	PPM	lbs/AF	lbs/AF
			Site #5 T17 R16 S22 - Oxalis Soil				
0-1	1.4	5	6	22	606	2182	2209
1-2	1.1	4	5	18	382	1375	1397
2-3	1.8	6	5	18	287	1033	1057
3-4	2.5	9	4	14	216	778	801
4-5	5.2	19	4	14	250	900	933
		43		86		6268	6397
			Site #6 T16 R16 S22 - Lethent Soil				
0-1	19.1	69	5	18	647	2329	2416
1-2	3.2	12	5	11	456	1642	1665
2-3	1.4	5	3	11	388	1397	1413
3-4	1.6	6	2	7	368	1325	1338
4-5	2.5	9	2	7	295	1062	1078
		101		54		7755	7910
			Site #7 T15 R15 S26 - Levis Soil				
0-1	14.4	52	5	18	442	1591	1661
1-2	8.4	30	3	11	258	929	970
2-3	6.8	24	3	11	175	630	665
3-4	3.6	13	2	7	147	529	549
4-5	2.3	8	2	7	128	461	476
		127		54		4140	4321
			Site #8 T15 R14 S27 - Oxalis Soil				
0-1	7.7	28	6	22	505	1818	1868
1-2	22.1	80	3	11	309	1112	1203
2-3	48.1	173	2	7	212	763	943
3-4	53.9	194	2	7	210	756	957
4-5	174.0	626	2	7	202	727	1360
		1101		54		5176	6331
			Site #9 T15 R13 S26 - Panoche Soil				
0-1	6.6	24	4	14	444	1598	1636
1-2	2.7	10	3	11	312	1123	1144
2-3	11.1	40	3	11	214	770	821
3-4	14.2	51	4	14	160	576	641
4-5	22.6	81	2	7	149	536	624
		206		57		4603	4866

TABLE 8 (Cont.)

Depth Ft	NO_3-N PPM	NO_3-N lbs/AF	NH_3-N PPM	NH_3-N lbs/AF	Organic N PPM	Organic N lbs/AF	Total N lbs/AF
			Site #10 T14 R12 S26 - Lost Hills Soil				
0-1	31.2	112	3	11	434	1562	1685
1-2	35.2	127	2	7	247	889	1023
2-3	42.7	154	2	7	182	655	816
3-4	52.6	189	1	4	175	630	823
4-5	55.3	199	1	4	163	587	790
		781		33		4323	5137
			Site #11 T14 R12 S13 - Panoche Soil				
0-1	43.1	155	3	11	401	1444	1610
1-2	21.9	79	2	7	271	976	1062
2-3	9.5	34	1	4	168	605	643
3-4	8.1	29	1	4	150	540	573
4-5	6.3	23	1	4	149	536	563
		320		30		4101	4451
			Site 12 T13 R13 S23 - Panoche Soil				
0-1	14.2	51	4	14	660	2376	2441
1-2	3.8	14	2	7	521	1876	1897
2-3	3.2	12	1	4	481	1732	1748
3-4	8.1	29	1	4	398	1433	1466
4-5	11.1	40	1	4	348	1253	1297
		146		33		8670	8849
			Site #13 T12 R13 S25 - Oxalis Soil				
0-1	17.6	63	7	25	687	2473	2561
1-2	2.9	10	4	14	427	1537	1561
2-3	5.9	21	2	7	328	1181	1209
3-4	0.9	3	4	14	279	1004	1021
4-5	0.9	3	4	14	250	900	917
		100		74		7095	7269

to 8670 pounds per acre. Nitrate -N was the next largest constituent with a range of 28 to 1101 pounds per acre. The amount of NH_3 in the soil was low but rather consistent with a range of 30 to 86 pounds per acre.

Soil organic matter is the source of the organic nitrogen which comprised more than 98 percent of the total nitrogen in some of the sites. Soil organic matter is an ill defined term used to cover

organic materials in all stages of decomposition from humus, which is relatively resistant to further decomposition, to fresh crop residues that are subject to fairly rapid decomposition. Studies have shown that this organic nitrogen exists about 5-10 percent in the form of nucleic acids; about 30 to 40 percent in the form of proteins or its derivatives and about 10 to 15 percent as amino sugar. Most of the remaining nitrogen has not been characterized. Although quite refractory some of this nitrogen can be converted by bacterial action to NH_3 and/or NO_3.

Although there were several exceptions, most often in the first five feet of soil, the nitrate nitrogen and organic nitrogen concentrations were greatest in the surface foot. This is probably due to the higher rate of mineralization in the better aerated surface soil and residual nitrates from fertilizer, the absorption of the NH_3 fertilizer by the clay complex, and the result of the organic matter incorporated into the surface soils.

The distribution of the various nitrogen forms did not show any distinct pattern in relation to soil series, physiographic position or geomorphic area. The minimum, maximum and average NO_3-N and organic N contents for several soil types and physiographic positions are listed in Table 9. The NO_3-N concentration in the seven basin rim soils ranged from a minimum of one to a maximum of 100 with an average of 14 parts per million. These figures include one site which had an extremely high concentration. If this site is excluded the average NO_3-N would be only five parts per million.

The NO_3-N concentration of five recent alluvial soils ranged from a minimum of 2 to a maximum of 35 with an average of about 11 parts

TABLE 9

Minimum, Maximum and Average NO_3-N and Organic N Concentrations at the Various Sites by Soil Type, 0-5 Feet

	No. of	Minimum		Maximum		Average	
	Sites	NO_3-N	Org.N	NO_3-N	Org.N	NO_3-N	Org.N
		p.p.m.		p.p.m.		p.p.m.	
Soils							
Basin Rim							
Oxalis	4	2	250	100	412	20	349
Lethent	2	1	297	5	511	4	379
Levis	1	2	207	10	253	7	230
Recent Alluvial							
Panoche	5	2	156	35	525	11	349
Old Alluvial							
Lost Hills	1	22	225	94	248	42	240

per million. These data would indicate that there is about as much variation within the same soil type as there is between the different soil types and physiographic positions.

The data as listed in Table 10 also indicates that there are variations in the NO_3-N concentrations among the holes located at the same sites in similar soil material. In some sites there were percentage differences ranging up to 800 percent and actual differences up to 70 parts per million of nitrogen.

Statistical analyses were made on the variability of the nitrate values at each of the transect sites. These determinations include the averages, standard deviation and the standard error of the mean of the nitrate concentrations from the five borings at each site. The results of these calculations are presented in Table 11.

The organic nitrogen concentrations, although not exhibiting as great a percentage range as the NO_3-N, varied considerably in actual values. Again there was as great or greater variation among the sites of similar soil types as there was among the different soil types and physiographic position. There were also differences among the five holes at the same site, indicating significant variations within small areas.

The NH_3 content of the soil at all of the sites ranged from about 1 to 7 parts per million. These values were relatively consistent at all of the sites. There were no appreciable differences between soil type or physiographic position.

If it is assumed that the concentrations determined for the individual sites are representative of the whole area, the average and total quantity of nitrogen in the top five feet of soil of the study area would be 6,142 pounds per acre of 2,056,660 tons and is segregated as shown in Table 12.

Nitrogen in the Substrata

The results of the laboratory analyses for the various forms of nitrogen in the substrata of the transect sites as expressed in parts per million and pounds per acre-foot are summarized in Table 13. The substrata as used in this study is defined as those soil horizons between 5 and 40 foot depths.

Because of the apparent correlation between nitrogen concentration and the fan-interfan position, this was used as a basis to determine the total quantity of nitrogen in the substrata of the area. These values were determined by multiplying the weighted average of the nitrogen concentrations in the 5-40 feet depths of the sites

TABLE 10

The Average NO3-N and Organic N Content in Parts Per Million in the 0-5 Foot Depth for the 5 Holes Within the Various Sites

Site		Hole # a		b		c		d		e		Average	
No.	Soil Series	NO_3-N	Org.N	NO_3-N	Org.N	NO_3-N	Org.N	NO_3-N	Org.N	NO_3-N	Org.N	NO_3-N	Org.N
1	Oxalis	23	250	5	338	6	387	4	352	5	375	8	340
5	"	7	211	2	360	2	389	2	379	2	402	3	371
8	"	30	308	49	277	68	313	100	269	60	290	61	291
13	"	5	371	4	412	5	409	9	391	6	388	6	394
2	Lethent	5	327	1	297	1	302	2	310	1	352	2	318
6	"	5	452	5	405	5	511	5	304	8	483	5	431
7	Levis	10	207	10	225	2	233	5	231	8	253	7	230
3	Panoche	3	382	1	335	2	244	2	310	1	236	2	301
4	"	11	394	4	319	16	361	17	411	8	345	11	366
9	"	8	200	25	239	9	266	11	261	18	316	18	256
11	"	35	197	13	156	10	261	13	241	18	283	18	228
12	"	24	466	3	525	5	475	4	440	5	461	8	483
10	Lost Hills	22	238	42	248	94	225	24	265	35	225	42	240

TABLE 11

Summary of NO_3-N in Parts per Million, Standard Deviations and Standard Error of Mean for the Five Holes at Each Nitrate Site

Depth Ft.	a	b	c	d	e	Avg.	(1) σ	(2) σm
Site #1 T19S R18E S23 - Oxalis Clay								
0-1	10	2	2	2	2	4	3	4
1-2	67	4	10	10	2	19	27	34
2-3	26	2	6	3	2	8	10	13
3-4	12	3	2	2	3	4	4	6
4-5	19	15	11	4	15	13	6	7
Site #2 T19 R19 S27 - Lethent Soil								
0-1	6	1	1	1	0	2	2	2
1-2	15	1	1	2	2	5	6	7
2-3	2	1	1	2	1	1	1	1
3-4	2	1	1	1	2	1	1	1
4-5	2	1	1	2	1	1	1	1
Site #3 T19 R17 S20 - Oxalis Soil								
0-1	3	3	4	4	3	3	1	1
1-2	2	2	3	2	1	2	1	1
2-3	2	1	1	1	1	1	1	1
3-4	4	1	1	1	1	1	1	2
4-5	4	1	1	1	1	1	2	2
Site #4 T19 R16 S15 - Panoche Soil								
0-1	12	2	16	16	13	12	6	7
1-2	14	2	22	19	6	12	8	11
2-3	15	1	19	16	15	13	7	8
3-4	9	7	13	12	4	9	4	5
4-5	5	9	8	25	2	10	9	11
Site #5 T17 R16 S22 - Oxalis Soil								
0-1	1	2	2	1	0	1	1	1
1-2	12	1	2	1	1	3	6	7
2-3	5	1	1	1	1	2	2	2
3-4	8	1	1	1	2	2	3	4
4-5	11	2	3	4	5	5	3	4

(1) σ - Standard deviation of the mean, all values $\pm$
(2) σm - Standard error of mean (95 percent confidence interval)

Depth Ft.	a	b	c	d	e	Avg.	(1) σ	(2) σm
			Site #6 T16 R16 S22 - Lethent Soil					
0-1	16	17	17	15	30	19	6	8
1-2	2	5	4	2	4	3	1	1
2-3	1	2	1	2	1	1	1	1
3-4	2	2	1	2	2	2	1	1
4-5	3	2	2	2	2	2	1	1
			Site #7 T15 R15 S26 - Levis Soil					
0-1	16	20	7	13	16	14	5	6
1-2	17	11	1	5	8	8	6	8
2-3	11	10	1	2	10	7	5	6
3-4	5	6	1	2	5	4	2	2
4-5	3	2	1	2	3	2	1	1
			Site #8 T15 R14 S27 - Oxalis Soil					
0-1	14	6	4	10	5	8	4	5
1-2	24	28	16	29	15	22	7	8
2-3	32	30	32	120	28	48	40	50
3-4	29	48	67	42	85	54	22	27
4-5	54	130	219	303	160	175	93	115
			Site #9 T15 R13 S26 - Panoche Soil					
0-1	1	11	8	6	11	7	4	5
1-2	2	6	2	1	1	2	2	2
2-3	23	22	7	1	4	11	10	13
3-4	14	33	13	8	3	14	11	14
4-5	1	52	18	40	2	23	23	28
			Site #10 T14 R12 S26 - Lost Hills Soil					
0-1	2	4	97	14	40	31	40	50
1-2	3	26	70	20	40	32	33	40
2-3	16	46	82	26	44	43	25	31
3-4	40	50	101	29	44	53	28	35
4-5	48	48	101	33	50	57	52	65
			Site #11 T14 R12 S13 - Panoche Soil					
0-1	79	48	29	30	30	43	21	26
1-2	61	10	8	16	15	22	22	28
2-3	17	2	3	10	15	9	7	8
3-4	11	1	5	6	17	8	6	8
4-5	7	2	6	3	13	6	5	6

TABLE 11 (cont.)

Depth Ft.	a	b	c	d	e	Avg.	(1) σ	(2) σm
			Site #12 T13 R13 S23 - Panoche Soil					
0-1	64	5	2	1	1	14	28	34
1-2	13	3	1	1	1	4	5	6
2-3	8	2	1	3	2	3	2	3
3-4	14	3	7	8	9	8	4	5
4-5	23	3	12	6	12	11	8	9
			Site #13 T12 R13 S25 - Oxalis Soil					
0-1	18	14	15	19	23	18	4	5
1-2	2	2	2	3	5	3	1	1
2-3	1	1	5	22	1	6	9	11
3-4	1	2	1	1	1	1	1	1
4-5	1	2	1	1	0	1	1	1

TABLE 12
Average Pounds Per Acre and Total N in the Study Area in the 0-5 Foot Soil Depth

NO_3-N lbs/ac.	NO_3-N Tons	NH_3-N lbs/ac.	NH_3-N Tons	Organic N lbs/ac.	Organic N Tons	Total N lbs/ac.	Total N Tons
258	86,370	54	18,400	5,830	1,951,940	6,142	2,056,600

within the individual fans, or those sites most representative of them, by the acreages of the fans. The total nitrogen and pounds per acre for each of the nitrogen forms on each alluvial fan are listed in Table 14.

The total nitrogen in the substrata is 8,193,080 tons or about 24,490 pounds per acre. Nitrate N accounts for 1,496,000 tons or 4,470 pounds per acre of the total. The concentration of nitrate N ranged from a low of 87 pounds at site 5, a Panoche soil on the Los Gatos Creek fan to a high 28,353 pounds per acre at site 8, an Oxalis soil on the Panoche-Cantua interfan.

The total organic N in the Substrata was 6,559,250 tons or an average of 19,730 pounds per acre. The concentration of the

TABLE 13

NO_3-N, NH_3-N and Organic N in PPM and Pounds Per Acre in the Soil Substrata*

Site No.	Depth in feet	NO_3-N PPM**	NO_3-N lbs.	NH_3-N PPM**	NH_3-N lbs.	Organic N PPM**	Organic N lbs.	Total N lbs.
1	5-40	3.7	467	2.9	368	144	18,197	19,032
2	5-12.5	1.5	40	3.0	82	199	5,383	5,505
3	5-40	0.7	87	3.2	409	232	29,284	29,780
4	5-32	41.4	4,019	2.9	277	202	19,560	23,867
5	5-40	13.4	1,693	2.0	250	152	19,109	21,052
6	***							
7	5-6	1.6	6	3.0	11	138	497	514
8	5-40	205.0	28,353	1.8	232	118	14,810	43,395
9	5-40	135.8	17,105	2.2	282	112	14,164	31,551
10	5-40	60.5	7,642	1.1	137	108	13,573	23,352
11	5-40	2.0	252	1.5	186	145	17,691	18,129
12	5-30	12.3	1,106	1.4	128	185	16,686	17,920
13	5-10	1.8	32	2.3	42	235	4,230	4,304

* 5-40 feet or to water table
** Based on Apparent Specific Gravity of 1.32
*** Water Table at 5 feet

individual sites ranged from a minimum of 13,573 to a maximum of 29,284 pounds per acre. Although this is a large variation, the percentage differences are relatively small when compared with the variations that occur in the nitrate concentrations.

The distribution of the relative concentrations of NO_3-N, NH_3-N and organic N throughout the profile at all the transect sites is shown in Figures 4 through 16.

The nitrate -N generally was greatest in the upper part of the substrata, there were exceptions and the peak concentrations occurred at any depth.

The ammonia concentrations were relatively low, generally less than five parts per million. Although percentage-wise there was a large variation between sites, the differences in actual quantities when compared to differences in the other forms were small.

Although the quantity of organic N decreased with depth, it was still the dominant type except in site 8. At site 9 organic N was only slightly more than NO_3-N. A few substrata contained

TABLE 14

Total N in the 5 - 40 foot Substrata by Alluvial Fan

Geomorphic Area	Area	NO_3-N		NH_3-N		Organic-N		Total N	
	Acres	lbs/Ac	Total Tons	lbs/Ac	Total Tons	lbs/Ac	Total Tons	lbs/Ac	Total Tons
Laguna Seca - Little Panoche I.F.*	9,970	7,642	38,080	137	680	13,573	67,640	21,352	106,400
Little Panoche Creek	10,340	252	1,300	186	960	17,691	91,480	18,129	93,740
Little Panoche - Panoche I.F.	63,090	7,642	241,050	137	4,320	13,573	428,140	21,352	673,510
Panoche Creek	111,230	252	14,030	186	10,340	17,691	983,880	18,129	1,008,250
Panoche-Cantua I.F.	90,130	22,725	1,024,090	257	11,580	14,487	652,850	37,469	1,688,520
Cantua Creek	45,380	270	6,130	388	23,740	23,740	538,680	24,398	553,610
Cantua-Los Gatos I.F.	73,220	2,945	107,810	280	10,250	19,730	722,230	22,955	840,380
Los Gatos Creek	245,460	277	33,990	388	47,620	23,740	2,913,610	24,405	2,995,220
South of Los Gatos Creek I.F.	20,340	2,945	29,950	280	2,850	19,730	200,650	22,955	233,450
Total (Ave)	669,160	4,470	1,496,430	290	97,400	19,730	6,599,250	24,490	8,193,080

*I.F. - Interfan

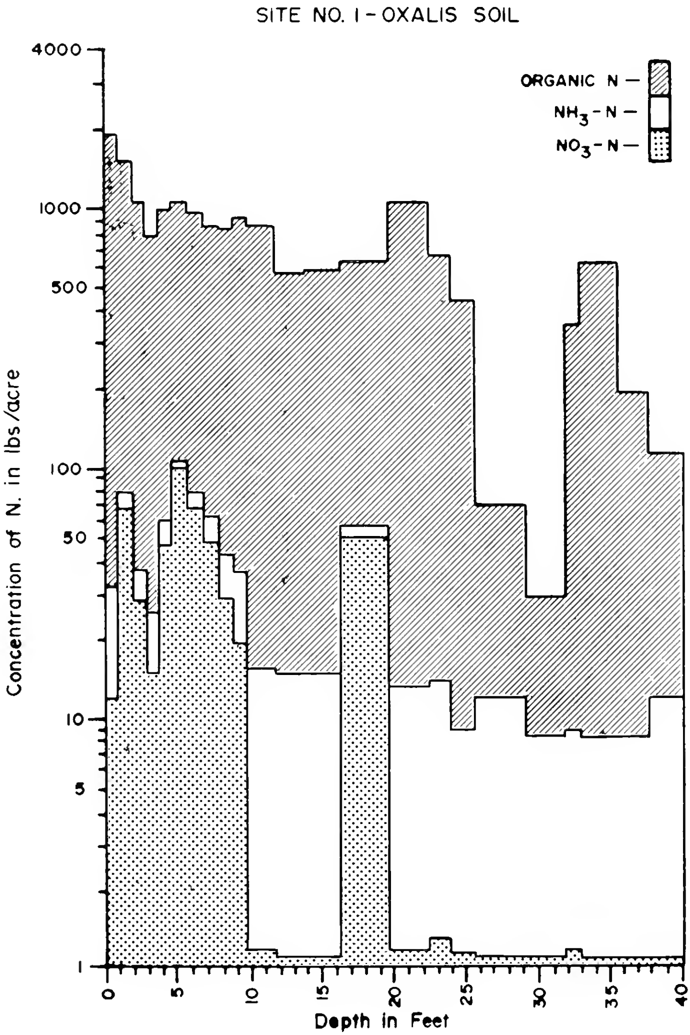

FIG. 4 – DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

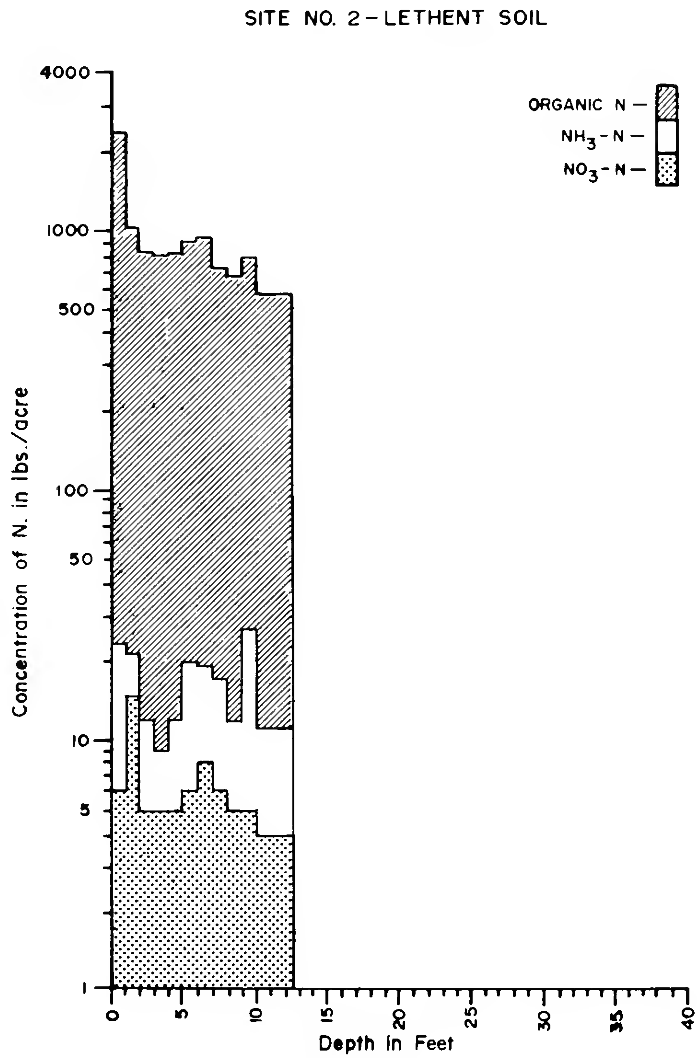

FIG. 5 - DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

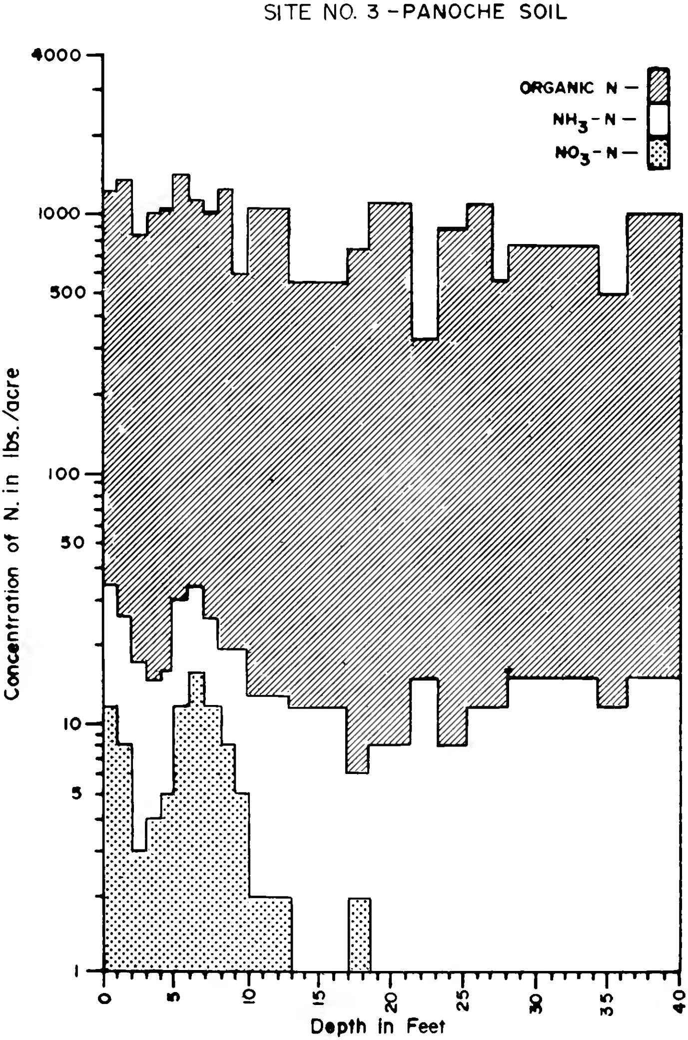

FIG. 6 – DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

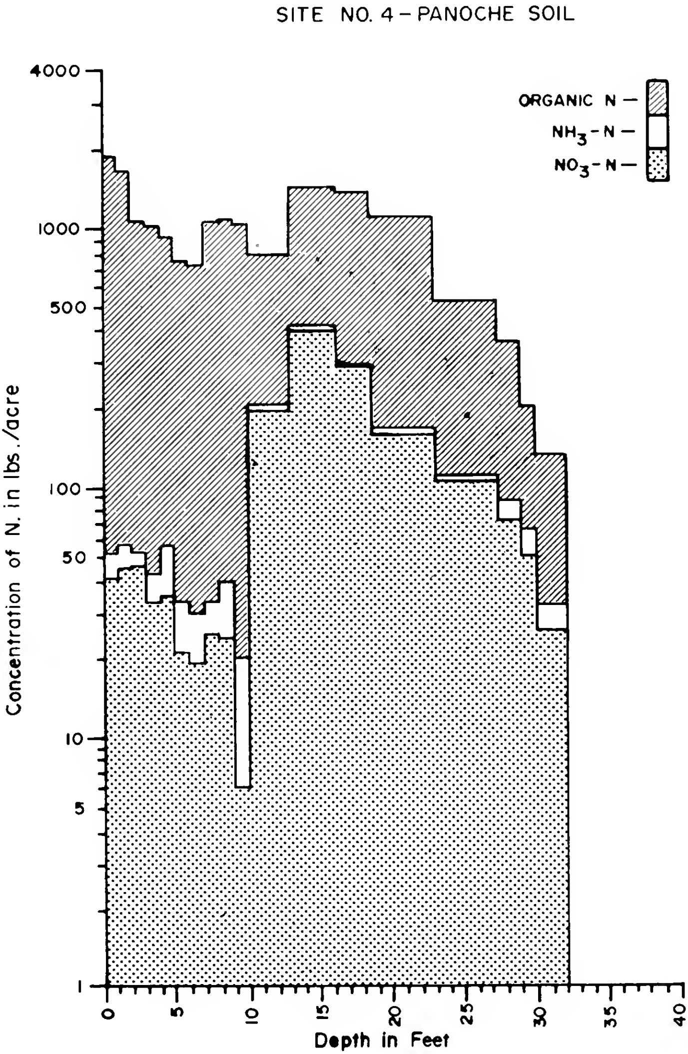

FIG. 7 – DISTRIBUTION OF NO_3–N, NH_3–N AND ORGANIC-N BY SAMPLING DEPTH

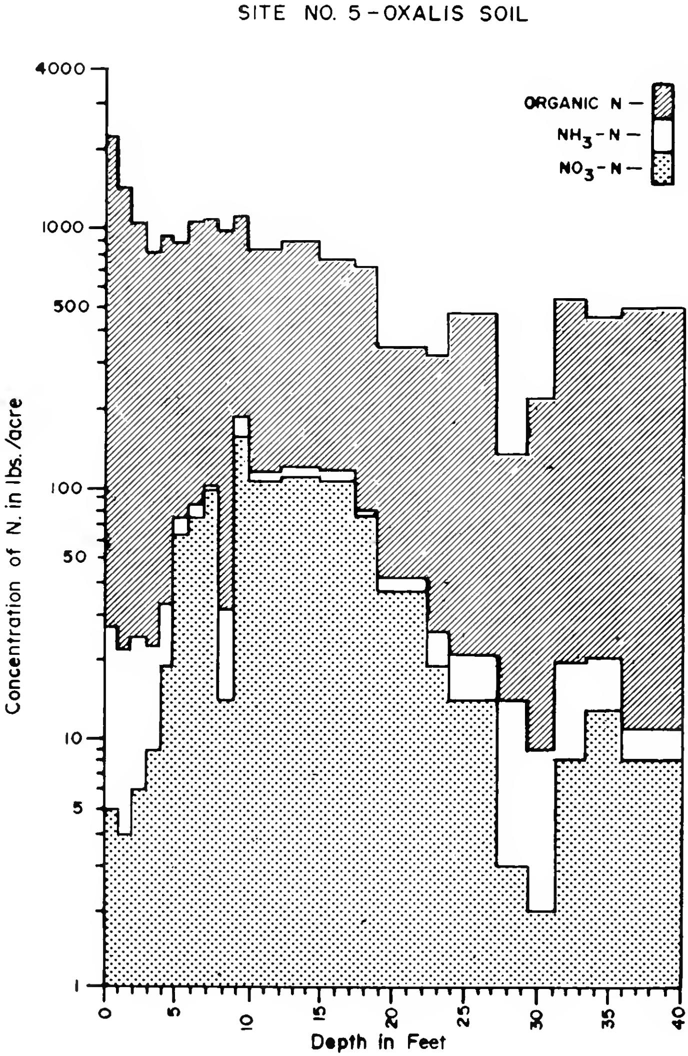

FIG. 8 - DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

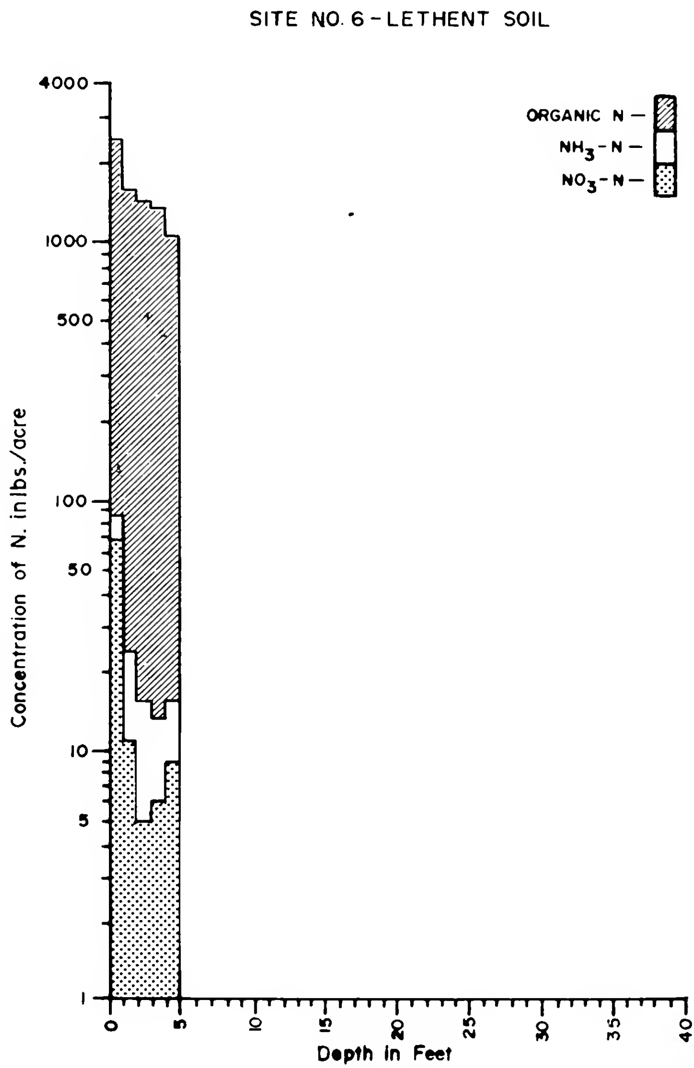

FIG. 9 – DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

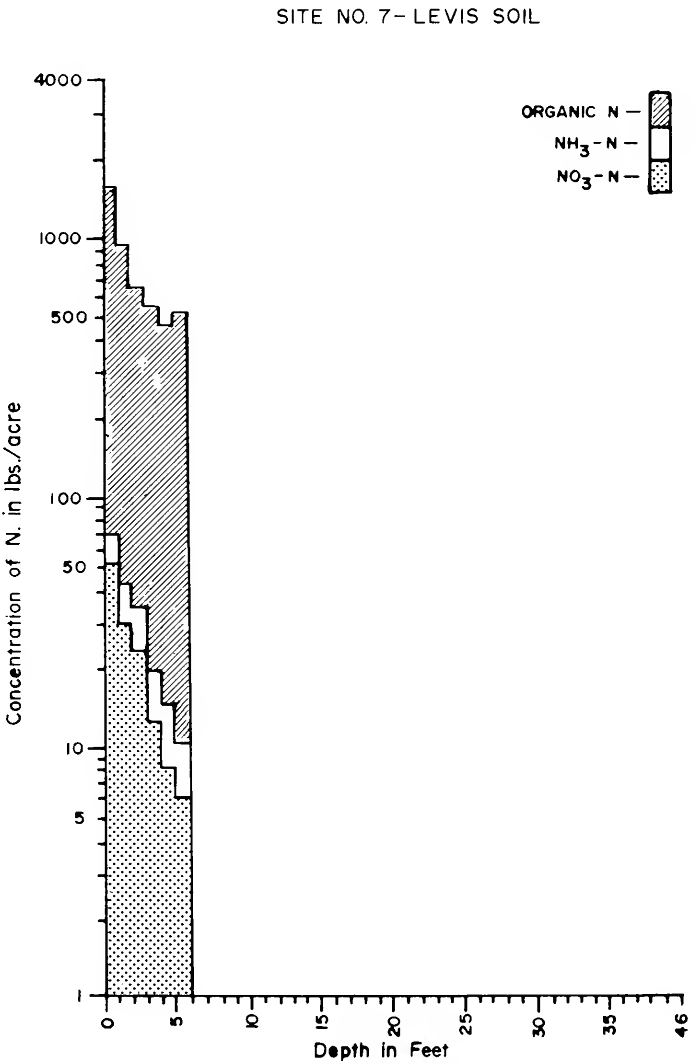

FIG. 10 - DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

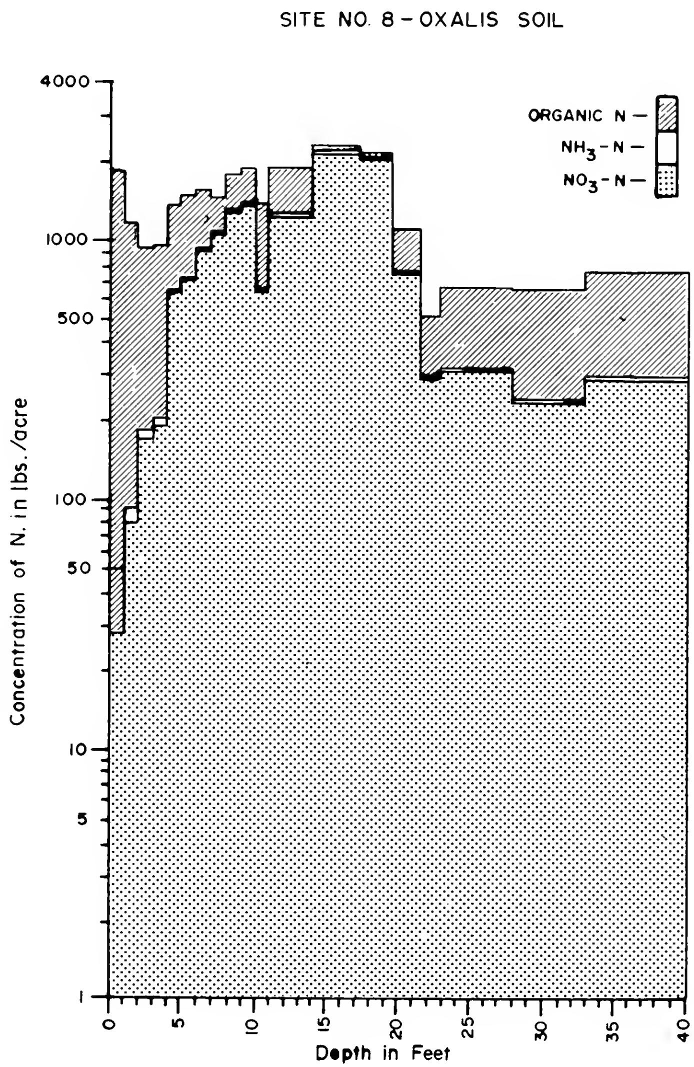

FIG. 11 - DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

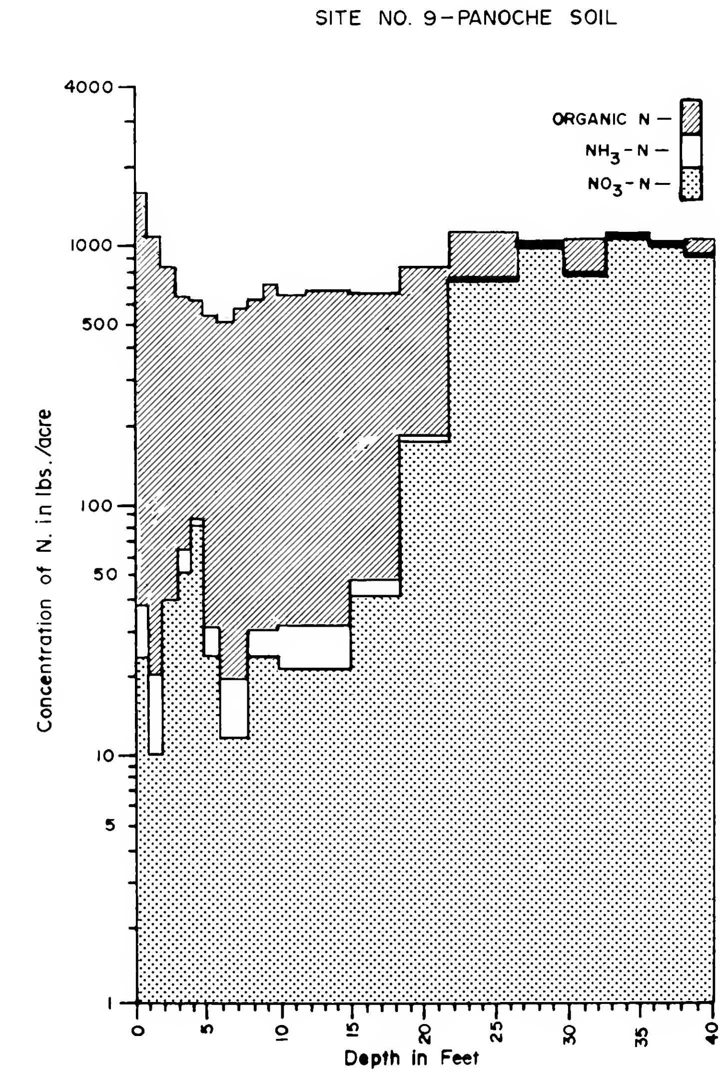

FIG. 12 — DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

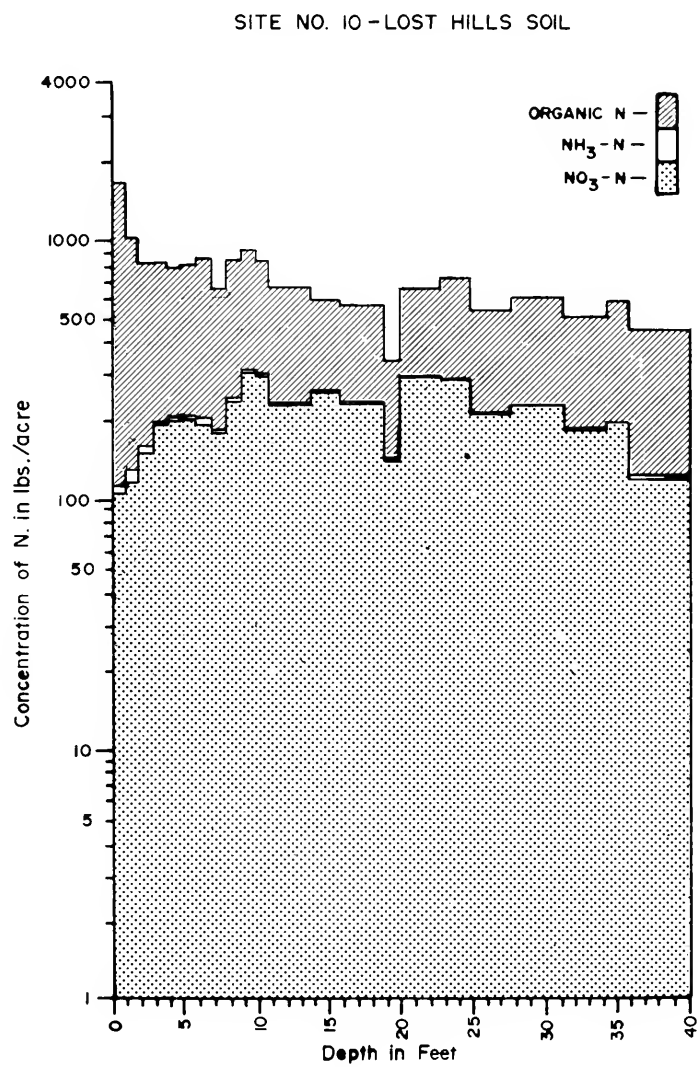

FIG. 13 - DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

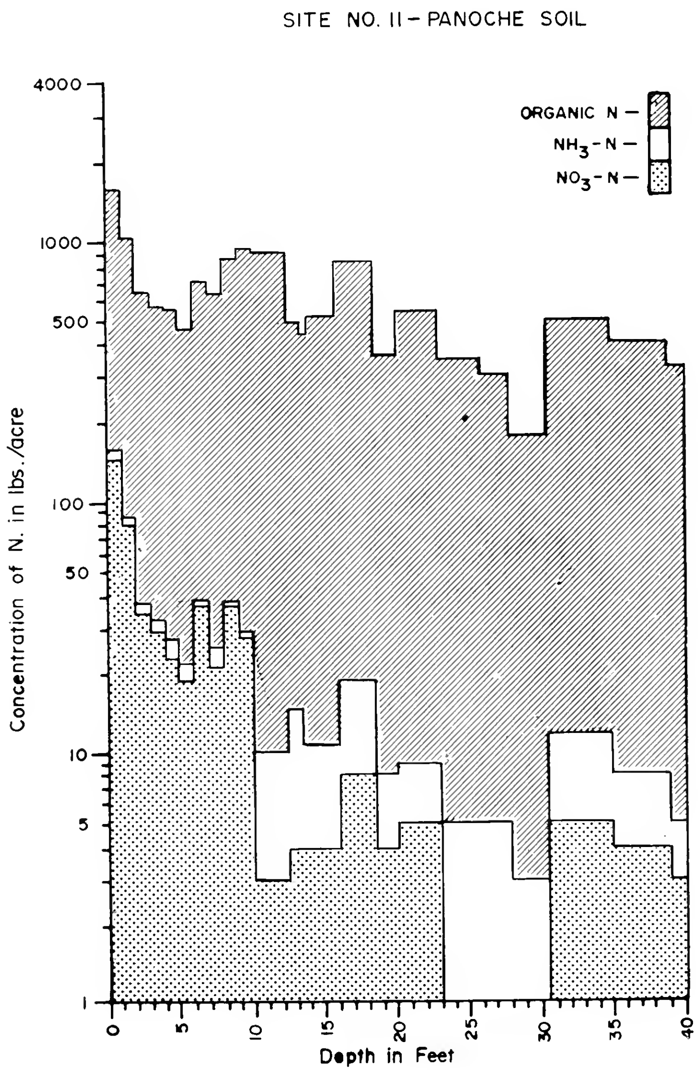

FIG. 14 - DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

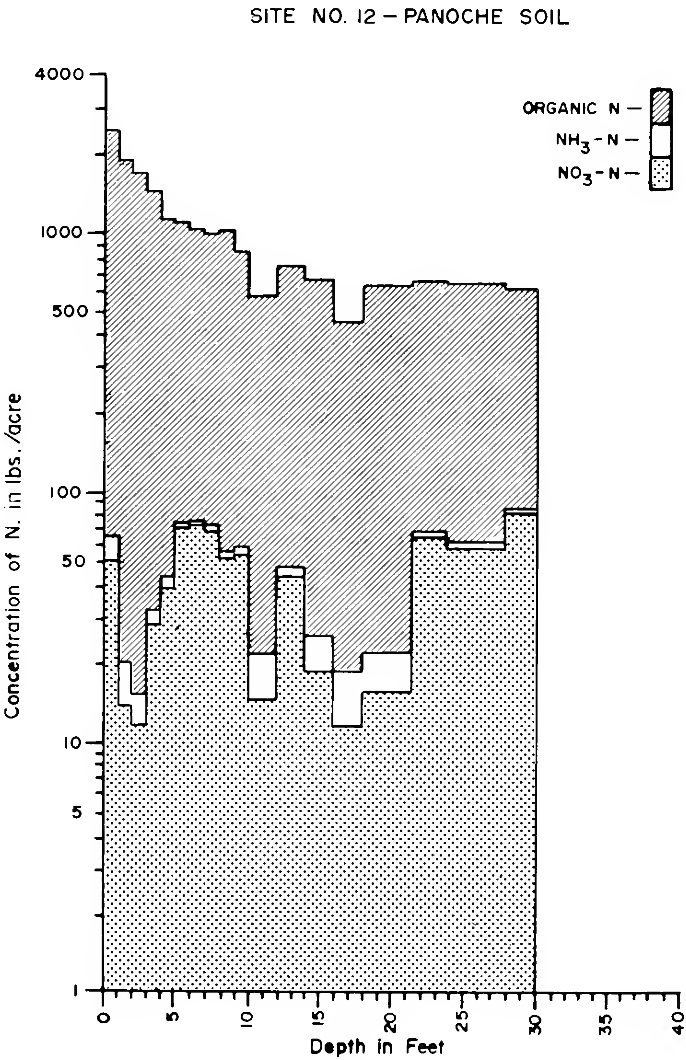

FIG. 15 – DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

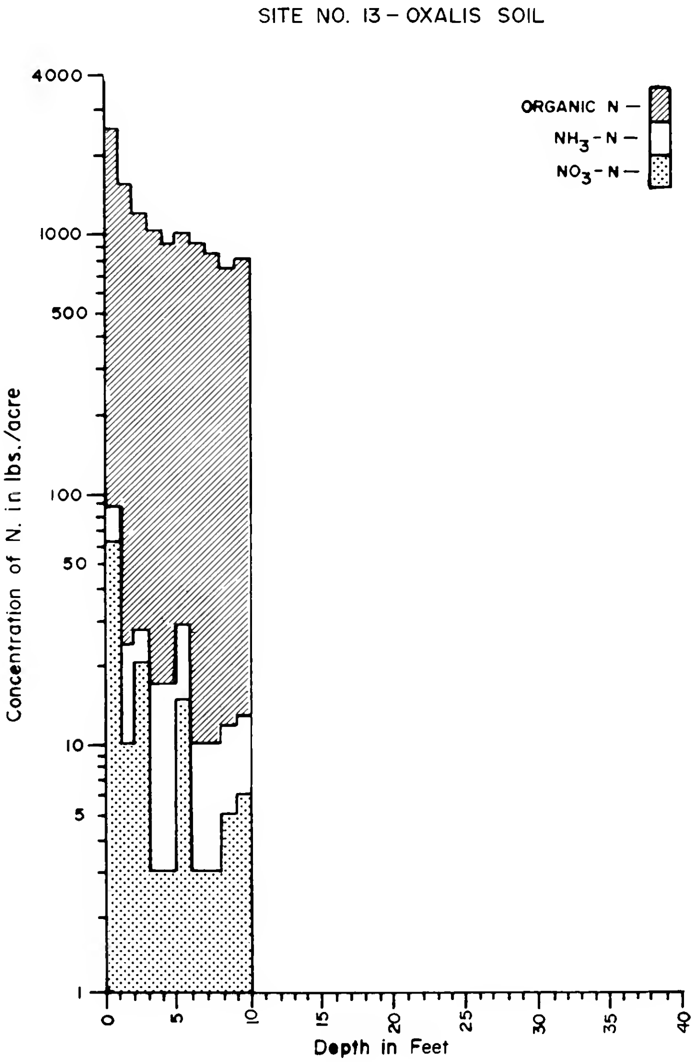

FIG. 16 – DISTRIBUTION OF NO_3-N, NH_3-N AND ORGANIC-N BY SAMPLING DEPTH

less than 10, however, normally they contained more than 100 parts per million. The organic N concentrations were higher on the alluvial fans than on the interfans and in both fan and interfan areas there is an increase in concentration from north to south.

Sites No. 8, 9, and 10 have unusually high concentrations of nitrates. They represent different soil series and physiographic position. However, they do have a common factor in that they are located on similar geomorphic units; that is, interfan areas between the larger streams, Little Panoche, Panoche and Cantua Creeks. These areas have been subjected to less surface flooding and consequently there has been less leaching of the nitrates from the soil profile. There is also the possibility that because less water has moved through the soils there have been fewer saturated conditions therefore less denitrification has occurred to reduce the nitrate concentrations.

Nitrogen in Groundwater

About 25 percent of the ultimate water demand will be met from the groundwater of the area, therefore, it is necessary to know the amount of nitrate in this body of water in order to predict the nitrate-nitrogen content of the agricultural drainage effluent. Generally data from the wells above the Corcoran clay show a decrease in the nitrate concentration with increasing depth. The wells which have their primary yields from the Sierra sediments have lower nitrate concentrations than those wells that produce from the Coast Range sediments.

A description of nitrate concentrations in water above the Corcoran clay by well depth interval as prepared by the Geology Branch, USBR, Sacramento is presented below:

0-50 foot well depth

As shown in Tables 15 through 19, the highest NO_3-N values appear to be in the 0-50 foot depth on the Los Gatos-Zapatos interfan in Coast Range material. However, this concentration of 122 mg/l NO_3-N is based on an average of only two samples. The 0-50 foot depth on the Panoche-Cantua interfan has a mean of 52 mg/l NO_3-N in Coast Range sediments based on 16 samples. The standard deviation for the 52 mg/l mean approached 68 mg/l indicating a wide range of NO_3-N concentrations within the 0-50 foot depth interval.

On the Panoche fan a mean NO_3-N concentration of about 36 mg/l in Coast Range sediments was computed for 53 samples including a very high NO_3-N value (560 mg/l) reported for USBR geohydrologic observation hole No. 14S/14E/28R2. Excluding this high analysis, the mean NO_3-N content was 16 mg/l, with the next highest NO_3-N being 160 mg/l.

TABLE 15

Summary a/ of Nitrate Nitrogen and Standard Deviations in Milligrams per Liter for Wells and USBR Geohydrologic Observation Holes Above the Corcoran Clay - 0-50 Foot Depth

GEOMORPHIC UNITS	No. of analyses	0-50 Ft. well depth — Yield primarily from: Sierran sediments	Coast Range sediments
LOS BANOS CR. - L. PANOCHE INTERFAN	1		10.2
LITTLE PANOCHE FAN	5		18.5 ± 14.0
LITTLE PANOCHE - PANOCHE INTERFAN	3		7.6 ± 4.6
PANOCHE FAN	53b/		25.9 ± 76.3
	52c/		15.6 ± 24.8
	1	1.0	
PANOCHE - CANTUA INTERFAN	16		52.5 ± 67.6
CANTUA FAN	14		6.1 ± 9.3
CANTUA - LOS GATOS INTERFAN	7		22.7 ± 29.6
LOS GATOS FAN	40		30.1 ± 77.3
	16	2.4 ± 4.0	
LOS GATOS - ZAPATOS INTERFAN	2		122.4 (aver.)
MENDOTA - FIREBAUGH AREA	1		0.1
	2	0.9 (aver.)	
TOTAL SAMPLES ABOVE CORCORAN CLAY: 244	160		

a/Expressed as arithmetic mean plus or minus standard deviation.
b/Includes analysis from USBR geohydrologic observation hole No. 14S/14E-28R2 with a nitrate nitrogen value of 562 mg/l.
c/Excludes analysis from USBR geohydrologic observation hole No. 14S/14E-28R2.

TABLE 16

Summary of Nitrate Nitrogen and Standard Deviations in Milligrams per Liter for Wells and USBR Geohydrologic Observation Holes Above the Corcoran Clay - 50-150 Foot Depth

	50-150 ft. well depth		
		Yield primarily from:	
GEOMORPHIC UNITS	No. of analyses	Sierran sediments	Coast Range sediments
LOS BANOS CR. - L. PANOCHE INTERFAN			
LITTLE PANOCHE FAN			
LITTLE PANOCHE - PANOCHE INTERFAN			
PANOCHE FAN	2		1.4 (aver.)
PANOCHE - CANTUA INTERFAN	1		93.5
CANTUA FAN	1		0.1
CANTUA - LOS GATOS INTERFAN	1		0.7
LOS GATOS FAN	9		29.3 + 32.4
LOS GATOS - ZAPATOS INTERFAN			
MENDOTA - FIREBAUGH AREA	3	0.5 ± 0.3	
TOTAL SAMPLES ABOVE CORCORAN CLAY: 244	17		

TABLE 17

Summary of Nitrate Nitrogen and Standard Deviation in Milligrams per Liter for Wells and USBR Geohydrologic Observation Holes Above the Corcoran Clay - 150-300 Foot Depth

GEOMORPHIC UNITS	150-300 ft. well depth		
		Yield primarily from:	
	No. of analyses	Sierran sediments	Coast Range sediments
LOS BANOS CR. - L. PANOCHE INTERFAN			
LITTLE PANOCHE FAN			
LITTLE PANOCHE - PANOCHE INTERFAN			
PANOCHE FAN	7 1	 0.5	51.0 ± 117.2
PANOCHE - CANTUA INTERFAN	1		.6
CANTUA FAN			
CANTUA - LOS GATOS INTERFAN			
LOS GATOS FAN	2 1	 0.3	6.8 (aver.)
LOS GATOS - ZAPATOS INTERFAN			
MENDOTA - FIREBAUGH AREA	6 18	 0.3 ± 0.2	0.4 ± 0.5
TOTAL SAMPLES ABOVE CORCORAN CLAY: 244	36		

TABLE 18

Summary of Nitrate Nitrogen and Standard Deviations in Milligrams per Liter for Wells and USBR Geohydrologic Observation Holes Above the Corcoran Clay - 300-600 Foot Depth

GEOMORPHIC UNITS	No. of analyses	300-600 ft. well depth Yield primarily from: Sierran sediments	Coast Range sediments
LOS BANOS CR. - L. PANOCHE INTERFAN			
LITTLE PANOCHE FAN			
LITTLE PANOCHE - PANOCHE INTERFAN			
PANOCHE FAN	5	0.2 ± 0.3	
PANOCHE - CANTUA INTERFAN	3	0.9 ± 0.5	
CANTUA FAN	1		21.0
	2	0.2 (aver.)	
CANTUA - LOS GATOS INTERFAN			
LOS GATOS FAN	1		10.6
	8	1.4 ± 2.6	
LOS GATOS - ZAPATOS INTERFAN			
MENDOTA - FIREBAUGH	1		0.1
	2	0.1 (aver.)	
TOTAL SAMPLES ABOVE CORCORAN CLAY: 244	23		

TABLE 19

Summary of Nitrate Nitrogen and Standard Deviation in Milligrams per Liter for Wells and USBR Geohydrologic Observation Holes Above the Corcoran Clay - 600-800 Foot Depth

GEOMORPHIC UNITS	600-800- ft. well depth		
		Yield primarily from:	
	No. of analyses	Sierran sediments	Coast Range sediments
LOS BANOS CR - L. PANOCHE INTERFAN			
LITTLE PANOCHE FAN			
LITTLE PANOCHE - PANOCHE INTERFAN			
PANOCHE FAN			
PANOCHE - CANTUA INTERFAN			
CANTUA FAN			
CANTUA - LOS GATOS INTERFAN			
LOS GATOS FAN	5		0.2 ± 0.5
	2	0.5 (aver.)	
LOS GATOS - ZAPATOS INTERFAN	1		5.6
MENDOTA - FIREBAUGH AREA			
TOTAL SAMPLES ABOVE CORCORAN CLAY: 244	8		

Little Panoche fan has a mean NO_3-N concentration of 18 mg/l for five analyses with individual analyses ranging from 4 mg/l to 40 mg/l in the 0-50 foot interval.

Generally NO_3-N concentrations for the 0-50 foot depth in wells which obtain their yield from Sierran sediments is comparatively low, ranging from 0 to 14 mg/l (Los Gatos fan). Nitrate -N concentrations for USBR holes in Coast Range sediments in the interval are high, ranging from a trace up to 460 mg/l, as mentioned above. About five holes had nitrates in excess of 225 mg/l.

50-150 foot well depth

In the 50-150 foot depth range, one analysis on the Panoche-Cantua interfan was 93 mg/l in Coast Range sediments. On the Los Gatos fan the average for this depth was 29 ppm in Coast Range sediments. On the other fans and interfans in this depth range, mean NO_3-N was less than 2 mg/l, based on a small number of analyses in both Coast Range and Sierran sediments.

150-300 foot well depth

In the 150-300 foot depth interval Panoche fan had a high concentration of nitrate in Coast Range sediments; based on seven analyses the mean NO_3-N concentration was about 51 mg/l with a standard deviation of 117 mg/l. The range was from 1 to 320 mg/l. For other fans and sediments concentrations in this depth range were as much as 7 mg/l but were generally less than 1 mg/l.

300-600 foot well depth

In the 300-600 foot depth interval, NO_3-N concentrations are generally low, ranging from 0.1 to 2 mg/l, principally from Sierran aquifiers. Two wells in this depth zone producing from Coast Range sediments on the Cantua and Los Gatos fans had 22 and 10 mg/l, respectively of NO_3-N.

600-800 foot well depth

In the 600-800 depth interval, nitrate was low in both Sierran and Coast Range sediments with the highest NO_3-N being 6 mg/l in Coast Range sediments on the Los Gatos-Zapatos interfan.

The average NO_3-N concentration, about 0.5 mg/l, of the irrigation water from the wells in the area is much less than the average concentration of water in the material above the Corcoran as listed in Table 15 through 19. This is particularly true of the water in all depths of the Coast Range sediments and in the 0-50 depth of

the Sierran sediments, indicating that relatively small amounts of irrigation water is obtained from these sources. Also, as many of the wells are drilled below the Corcoran clay to depths of 2,000 feet or greater they pick up most of their water from strata not shown in this report.

Nitrogen Transformation and Movement in Lysimeters

The movement of residual nitrogen and applied fertilizer nitrogen in lysimeters was monitored under leaching and cropping regimes.

The initial NO_3-N levels of the soils ranged from 12 ppm in the Panoche clay subsoil to 115 ppm in the Lethent clay loam surface. The NO_3-N levels in leachates collected during initial leaching and before fertilization ranged from 4,290 ppm in the Oxalis clay to 560 ppm in the Panoche fine sandy loam. These high levels are believed due primarily to the change in the environment of the soils as a result of the screening, mixing and aeration during the filling of the lysimeters. These actions increased microbial activity which encouraged mineralization of some of the native organic nitrogen to nitrates.

After the high initial nitrate concentrations were recorded, a rapid drop in the nitrate levels occurred as additional water moved through the columns. When sufficient water had been applied to reduce the nitrate-N levels in the soil extracts from all sampling depths of the soil columns to less than 10 ppm, the NO_3-N concentrations in the leachates ranged from about 11 ppm for the Panoche fine sandy loam to about 115 ppm for the Oxalis clay. After the barley was planted and the ^{15}N enriched fertilizer applied, periodic samples were collected of the soil extracts at three depths in the columns and from the leachates. Data resulting from the analyses of these samples, based primarily on the atom percent excess ^{15}N, are presented in Tables 20 through 28. These data are averages of values from duplicate columns of each treatement.

Data for nitrogen content and the percentages which are attributable to fertilizer nitrogen in the "A" depths, 9 to 18 inches, are presented in Table 20. These data show that at this depth the highest percentage of fertilizer nitrogen appeared in those soils to which KNO_3 was applied. In Panoche fine sandy loam and Lethent sandy clay loam, respectively, 81 and 66 percent of the total nitrogen collected in the soil extract was fertilizer nitrogen. By comparison 14 and 27 percent of the nitrogen in the extract was fertilizer nitrogen when $(NH_4)_2SO_4$ was applied to Panoche clay loam and Oxalis clay and when sulfur coated urea was applied to Panoche fine sandy loam 25 percent of the extract from "A" depth was fertilizer nitrogen.

This would indicate that much of the ammonia-N is adsorbed by the

clay complex of the soil near the soil surface. Since only 30 percent of the sulfur coated urea was readily soluble and the remainder was treated to dissolve slowly, movement of nitrogen from the urea fertilizer could be expected to be approximately 30 percent of N movement from KNO_3 assuming appreciable hydrolosis did not occur. The data are in accord with these proportions. However, the system is complicated by nitrogen release from sulfur coated urea, hydrolosis of urea, nitrification and soil textural differences, therefore, the apparent proportionality may have resulted from compensating effects.

The nitrogen content and the percent fertilizer nitrogen in the soil extract at the "B" depths, 24 to 39 inches, are listed in Table 21.

TABLE 20

Nitrogen Content and Percent of Fertilizer Nitrogen in Soil Extracts from "A" Depths December 16, 1968 - August 18, 1969

Soil Type	Fertilizer	Water Applied In	Probe Depth In	Total N mg	Fertilizer N %
Panoche CL	$(NH_4)_2SO_4$	60.6	16	13.2	13.6
Panoche FSL	KNO_3	60.6	15	49.5	81.4
Lethent CL	KNO_3	60.6	9	34.2	66.1
Panoche FSL	S:Urea-N	60.6	11	15.2	25.0
Oxalis C	$(NH_4)_2SO_4$	60.6	18	16.5	27.3

TABLE 21

Nitrogen Content and Percent of Fertilizer Nitrogen in Soil Extracts from "B" Depths December 16, 1968 - August 18, 1969

Soil Type	Fertilizer	Water Applied In	Probe Depth In	Total N mg	Fertilizer N %
Panoche CL	$(NH_4)_2SO_4$	60.6	39	23.6	2.1
Panoche FSL	KNO_3	60.6	39	23.0	4.8
Lethent CL	KNO_3	60.6	24	14.2	23.9
Panoche FSL	S:Urea-N	60.6	33	14.4	4.2
Oxalis C	$(NH_4)_2SO_4$	60.6	31	36.0	1.4

The percent of fertilizer N of the total N collected from the "B" depths was less than 4.8 with the exception of the Lethent clay loam. The higher percentage of fertilizer N in the Lethent columns may have been because the suction probes were higher in the columns. These low values for the other columns indicate that little movement of the fertilizers occurred to depths of 31 to 39 inches.

The nitrogen content and percent fertilizer N for the "C" depth are shown in Table 22. At the most, 4.5 percent of the N collected from the probe came from the applied fertilizer. The highest percentage of fertilizer N was from the Lethent soil and least was from the Panoche fertilized with sulfur coated urea. These low values indicate, as did those of the "B" depths, that a very small percentage of the applied N moved through the soil columns.

TABLE 22

Nitrogen Content and Percent of Fertilizer in Soil Extracts from "C" Depths December 16, 1968 - August 18, 1969

Soil Type	Fertilizer	Water Applied In	Probe Depth In	Total N mg	Fertilizer N %
Panoche CL	$(NH_4)_2SO_4$	60.6	63	25.9	1.5
Panoche FSL	KNO_3	60.6	62	41.6	2.2
Lethent CL	KNO_3	60.6	60	19.8	4.5
Panoche FSL	S:Urea-N	60.6	58	20.9	1.4
Oxalis C	$(NH_4)_2SO_4$	60.6	56	20.5	1.5

Both the total nitrogen removed in the leachate and the percent of this total that was fertilizer nitrogen are listed in Table 23. The total N in the leachates ranged from 163 to 1010 milligrams, however, of these amounts less than 1.5 percent was from the applied fertilizer N.

TABLE 23

Nitrogen Content and Percent Fertilizer Nitrogen in the Leachate December 16, 1968 - August 18, 1969

Soil Type	Fertilizer	Water Applied In	Total N mg	Fertilizer N %
Panoche CL	$(NH_4)_2SO_4$	60.6	244	0.5
Panoche FSL	KNO_3	60.6	503	1.3
Lethent CL	KNO_3	60.6	163	0.7
Panoche FSL	S:Urea-N	60.6	302	0.8
Oxalis C	$(NH_4)_2SO_4$	60.6	1010	0.2

The total nitrogen removed in the soil extracts and leachates and the percentage of these values that were fertilizer nitrogen are shown in Table 24. Although the total N ranged from 231 milligrams in the

Lethent clay loam to 1083 milligrams in the Panoche fine sandy loam, only a small percentage of these totals were from fertilizer N. The percentages of fertilizer nitrogen in the total removed varied from 0.7 percent in the Oxalis clay to 12.2 percent in the Lethent clay loam. The higher percentages of fertilizer nitrogen recovered from those columns using KNO_3 are due primarily to the large quantities extracted from the "A" and "B" depths in these soils.

TABLE 24

Total Nitrogen Content of Soil Extracts, and Leachates and Percent Fertilizer Nitrogen for the Period December 13, 1968 to August 18, 1969

Soil Type	Fertilizer	(Soil - Fertilizer) N mg	Fertilizer N % of Total N
Panoche CL	$(NH_4)_2SO_4$	307	1.2
Panoche FSL	KNO_3	619	7.9
Lethent Cl	KNO_3	231	12.2
Panoche FSL	S:Urea-N	353	2.0
Oxalis C	$(NH_4)_2SO_4$	1083	0.7

The fertilizer nitrogen recovered as a percentage of the total fertilizer applied is shown in Table 25. The largest percentage, 3.91, of the fertilizer N recovered was from the Panoche fine sandy loam soil treated with KNO_3 fertilizer. The smallest percentage, 0.30 or 3.8 milligrams, was from the Panoche clay loam which was treated with $(NH_4)_2SO_4$. The most significant of these data are the amount of N recovered in the leachates. This is the quantity which under field conditions would enter the groundwater. The data show that the largest percentage of fertilizer nitrogen was recovered from the leachate of the light textured soil treated with KNO_3. It was a very small amount, representing 0.54 percent, 6.7 milligrams, of the total fertilizer applied. The least amount, 0.09 percent, 1.1 milligrams, was recovered from the Panoche clay loam soil that was treated with $(NH_4)_2SO_4$.

The total amounts of nitrate N in leachates from various soil columns treated with fertilizers and similar columns in which no fertilizers were applied are shown in Table 26.

The total NO_3-N removed varied in the fertilized columns from 1002 milligrams in the Oxalis clay to 28 milligrams in the Lethent clay loam and in the control columns from 788 milligrams in the Oxalis clay to 44 milligrams in the Lethent clay loam. As noted in Table 25, the maximum amount of fertilizer nitrogen recovered in the leachate was 0.54 percent or 6.7 milligrams from the Panoche fine sansy loam soil treated with KNO_3. Lesser amounts of fertilizer

TABLE 25

Recovery of Fertilizer Nitrogen from All Probes and Leachate for the Period - December 16, 1968 - August 18, 1969

Fertilizer	Soil Type	Sample Depth A		B		C		Leachate		Total	
		%	mg	%	mg	%	mg	%	mg	%	mg
$(NH_4)_2SO_4$	Pan.CL	0.14	1.8	0.04	0.5	0.03	0.4	0.09	1.1	0.30	3.8
KNO_3	Pan.FSL	3.22	40.3	0.09	1.1	0.07	0.9	0.54	6.7	3.91	48.9
KNO_3	Le. CL	1.81	22.6	0.27	3.4	0.07	0.9	0.10	1.2	2.24	28.1
S:Urea-	Pan.FSL	0.30	3.8	0.05	0.6	0.02	0.3	0.18	1.3	0.56	7.0
$(NH_4)_2SO_4$	Ox. C	0.36	4.5	0.04	0.5	0.02	0.3	0.16	2.0	0.58	7.3

TABLE 26

Nitrate -N Recovered in the Leachate of Soil Columns for the Period - December 16, 1968 - August 18, 1969*

Soil Type	Fertilizer	Nitrate N in Leachate Control	Fertilized
		mg	mg
Panoche CL	$(NH_4)_2SO_4$	133	143
Panoche FSL	KNO_3	259	431
Lethent CL	KNO_3	44	28
Panoche FSL	S:Urea-N	259	233
Oxalis C	$(NH4)_2SO_4$	788	1002

* Determined by measurements with the Orion Nitrate probe.

nitrogen were recovered from the other columns. Although large differences existed between the control and the fertilized columns for two of the soils and treatments (Table 26) these differences probably were due to analytical and soil variability rather than contributions from the applied fertilizers.

The significance of these data showing relatively large amounts of nitrogen removed from the columns is that only a very small percentage came from the applied fertilizers. Since the N in the leachate did not originate from the fertilizer applied during the study and the amount in the applied water was small, it had to come from the nitrogen in the soil at the start of the study.

The percentages of applied fertilizer nitrogen recovered by cropping are listed in Table 27. The highest percentage recovery by the barley was 73 percent from the Panoche fine sandy loam treated with KNO_3.

The lowest recovery, 47 percent, was from the urea treated Panoche fine sandy loam. This was probably due to the slow release rate of the sulfur coated urea. The recovery rates in the other treatments ranged from 63 to 65 percent.

TABLE 27

Recovery of Applied Fertilizer Nitrogen in the Barley and Grain Sorghum

Fertilizer	Soil Type	Barley (%AFN)*			Grain Sorghum (%AFN)		
		Straw	Grain	Total	Straw	Seed	Total
$(NH_4)_2SO_4$	Panoche CL	17.9	47.7	65.6	1.00	1.87	2.87
KNO_3	Panoche FSL	18.8	54.3	73.1	0.78	2.89	3.67
KNO_3	Lethent Cl	17.4	47.9	65.3	0.76	1.51	2.28
Urea-S	Panoche FSL	8.9	38.4	47.3	3.75	9.78	13.53
$(NH_4)_2SO_4$	Oxalis C	24.5	38.2	62.7	1.60	1.45	3.05

*Applied fertilizer nitrogen

The percentage of recovery by grain sorghum of the applied fertilizer nitrogen was greatest, 13.5 percent, in the Panoche fine sandy loam treated with the sulfur coated urea. The large recovery rate in this treatment was due to the great amount of residual N remaining in the soil as a result of the slow release of N from sulfur coated urea. The recovery rates in the other treatments ranged from 2.3 to 3.7 percent.

The percentages of the applied fertilizer nitrogen recovered by barley, grain sorghum and in the water samples collected between December 16, 1968 and August 18, 1969 are listed in Table 28. They ranged from a maximum 80.6 percent in Panoche fine sandy loam treated with KNO_3 to a minimum of 61.4 percent in Panoche fine sandy loam treated with sulfur coated urea. The recovery from the other systems ranged from 66.3 to 69.8 percent. The high percentage recovery from Panoche fine sandy loam soil treated with KNO_3 was probably because the NO_3-N form of fertilizer is more mobile in the soil and thus a greater root surface would be available to absorb the nitrogen.

These data do not account for a minimum of 19.4 and a maximum of 38.6 percent of the applied fertilizer nitrogen. No analyses have been made to determine the quantities that might be accounted for by the following: (1) volatilization and denitrification, (2) tied up in the plant roots, (3) adsorbed on the clay complex, (4) converted to an organic N form by soil bacteria, (5) remained in solution in the soil columns.

A portion of the residual N could be leached from the columns at a later date. To check this, water is still being applied to the columns and the leachate collected, however, as this is written no additional data are available.

TABLE 28

Recovery of Applied Fertilizer Nitrogen in Barley, Grain Sorghum, and Water Samples

Fertilizer	Soil Type	Barley	Grain Sorghum	Water Samples	Total
		%	%	%	%
$(NH_4)_2SO_4$	Panoche CL	65.6	2.87	0.30	68.77
KNO_3	Panoche FSL	73.0	3.67	3.91	80.58
KNO_3	Lethent CL	65.3	2.28	2.24	69.82
S:Urea-N	Panoche FSL	47.3	13.53	0.56	51.39
$(NH_4)_2SO_4$	Oxalis C	62.1	3.05	0.58	66.33

After the barley and grain sorghum crops were harvested, soil samples were taken from one of each of the paired lysimeters. These samples were analyzed for nitrate, organic N and amount of ^{15}N. The results of these tests for two of the lysimeters, one filled with Panoche FSL to which NO_3 fertilizer had been applied and one with Panoche Cl to which NH_4 fertilizer had been added, are in Table 29. The amounts of NO_3-N remaining in the soils were small and relatively consistent throughout the depths of the column. The two columns had essentially the same concentration and distribution of NO_3-N indicating no difference as a result of the applications of different types of fertilizers and soil textures. Only about 0.8 percent of the applied fertilizer remained in the soil in the nitrate form.

The majority of the applied nitrogen still in the soil was in the organic form and the largest amount of the ^{15}N, representing the applied nitrogen, remained in the top 15 centimeters of soil. This was because the returned crop residue was concentrated in this depth. The nitrogen fertilizer that remained in the organic fraction was 25.9 percent of that applied to the Panoche CL and 19.9 percent in the Panoche FSL.

The amounts of ^{15}N collected from the various sampling categories are listed in Table 30. These data show that an average of approximately 56 percent of the applied nitrogen was adsorbed up by the plants. The greatest removal of fertilizer N by the crops was from those lysimeters to which the nitrates were applied. There was no significant difference between the recovery of nitrogen in those lysimeters applied with NH_4 and urea. The residual nitrogen in the soil accounted for 13.1 to 30.5 percent or an average of about 24 percent of the applied nitrogen. The largest percentage of this fraction was found in those columns to which the ammonium type fertilizer had been applied. The quantity of the applied nitrogen that was unaccounted for ranged from 12.4 to 24.5 percent. This amount, aside from any possible analytical error, was lost through volatilization and denitrification.

TABLE 29

Recovery of Applied Fertilizer Nitrogen in the Nitrate and Organic Nitrogen Fraction from Two Lysimeters

Depth	Panoche CL (3) (NH_4SO_4)			Panoche FSL (6) (KNO_3)		
cm	NO_3-N ppm	Organic N ppm	Organic N ^{15}N mg	NO_3-N ppm	Organic N ppm	Organic N ^{15}N mg
0-15	43	358	22.2	41	246	12.6
15-30	38	310	4.2	48	220	1.0
30-45	42	288	1.7	47	211	1.3
45-60	45	353	0.8	35	243	3.4
60-75	41	281	0.6	49	234	1.5
75-90	49	284	0.5	42	234	1.0
90-105	45	176	0.4	43	213	0.3
105-120	50	178	0.1	44	175	0.4
120-135	43	127	0.5	37	209	1.1
135-150	43	134	0.4	50	261	0.9
150-165	65	124	1.0	45	233	0.3
165-180	42	148	0.5	56	238	1.1
			32.9			25.3
	546			537		
% Recovery	0.8		25.9	.8		19.9

TABLE 30

Summary of Applied ^{15}N Collected in the Various Categories

Lys #		Added Fertilizer	Water (2) Samples	Barley Thinnings	Harvested Barley Crop Net Removal	Milo Crop Removal	Residual Soil Nitrogen	% Recovery	^{15}N Unaccounted for
18	ug ^{15}N	+115,773	-536	-3,956	-49,145	-2,849	-25,030		24,257
NH_4	%	100%	0.5	3.4	42.4	2.5	30.3	79	21.0
11	ug ^{15}N	+354,762	-1,911	-6,987	-168,327	-32,262	-95,920		49,355
Urea	%	100%	0.5	2.0	47.4	9.1	27.0	86.1	13.9
9	ug ^{15}N	+116,357	-2,170	--	-67,665	-2,696	-15,340		28,486
NO_3	%	100%	1.9	--	58.2	2.3	13.2	75.5	24.5
6	ug ^{15}N	+ 116,357	-4,471	-1,261	-67,244	-3,614	-22,760		17,007
NO_3	%	100%	3.8	1.1	57.8	3.1	19.6	85.4	14.6
3	ug ^{15}N	+ 115,773	-340	-1,888	-60,085	-3,793	-35,260		14,407
NH_4	%	100%	0.3	1.6	51.9	3.3	30.5	87.6	12.4

1. - ug - Micrograms

2. - Includes leachate and suction probe samples

The conditions in the lysimeters will be different than field conditions. In the lysimeters, the root distribution is rather uniform throughout the soil area while in the field, especially in row crops, there would be areas between the rows where the root density is relatively low. Under these conditions, unless special care is taken in fertilizer placement, ie, in bands near the plant, and to avoid excess irrigation there could be greater losses of fertilizer nitrogen than indicated in the lysimeter studies.

Other lysimeter studies were conducted on the movement of nitrogenous salts in unsaturated flows under non-cropped conditions. Calcium nitrate and calcium chloride were applied to the columns and four inches of water added every two weeks. Under the aerobic conditions that existed in the upper portion of the column the NO_3's and Cl's moved with the percolating water. However, under the anaerobic conditions in the lower saturated portion of the column the nitrates were changed to a different form of N. Although part of this nitrogen was probably changed to an organic form in the cell material of microorganisms, most investigators attributed low recoveries primarily to denitrification (16). Chlorides, which are not subject to change to gaseous form under these conditions, were moved through the column with the percolating water and collected in the leachate. The movements of the nitrates and chlorides in one of the lysimeters are plotted in Figures 17 and 18.

It can also be noted from these data that approximately 36 inches of applied water was required to move the chlorides through the six foot soil column. The porosity of these soils is approximately 50 percent, therefore, the equivalent of about one pore volume of water moved the nitrate and chloride front through the columns.

A nitrogen balance sheet was prepared on one lysimeter to gain some insight on nitrogen gains and losses that occurred. The budget was prepared on lysimeter number 6 which was filled with Panoche fine sandy loam soil and treated with KNO_3. The measurements were made over approximately a years time, from December 13, 1968 to December 20, 1969, during which one fertilizer application was made and two crops, one of barley and one of milo, were grown and harvested.

The sources of nitrate-nitrogen available were the applied fertilizer, irrigation water, the residual nitrate in the soil at the start of the study and the nitrogen available as the result of mineralization of the organic nitrogen. One application of 1.27 grams of KNO_3 fertilizer which was equivalent to 100 pounds of nitrogen per acre, was added to the soil. The applied irrigation water, which contained about 0.5 parts per million of nitrate -N, added 0.09 grams of nitrogen or the equivalent of about 7 pounds per acre. The residual nitrate in the soil column at the start of the study was calculated to be 1.06 grams or equivalent of 83 pounds per acre. These three sources totaled 2.42 grams or equivalent to 190 pounds of nitrate -N per acre.

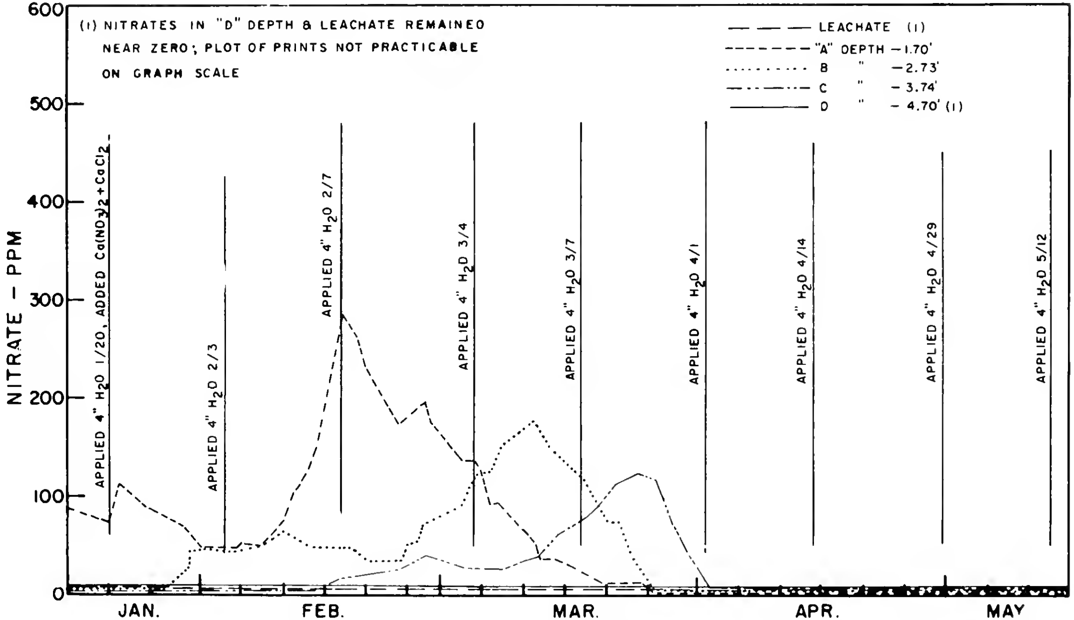

FIG. 17 – MOVEMENT OF NITRATES IN SOIL COLUMN

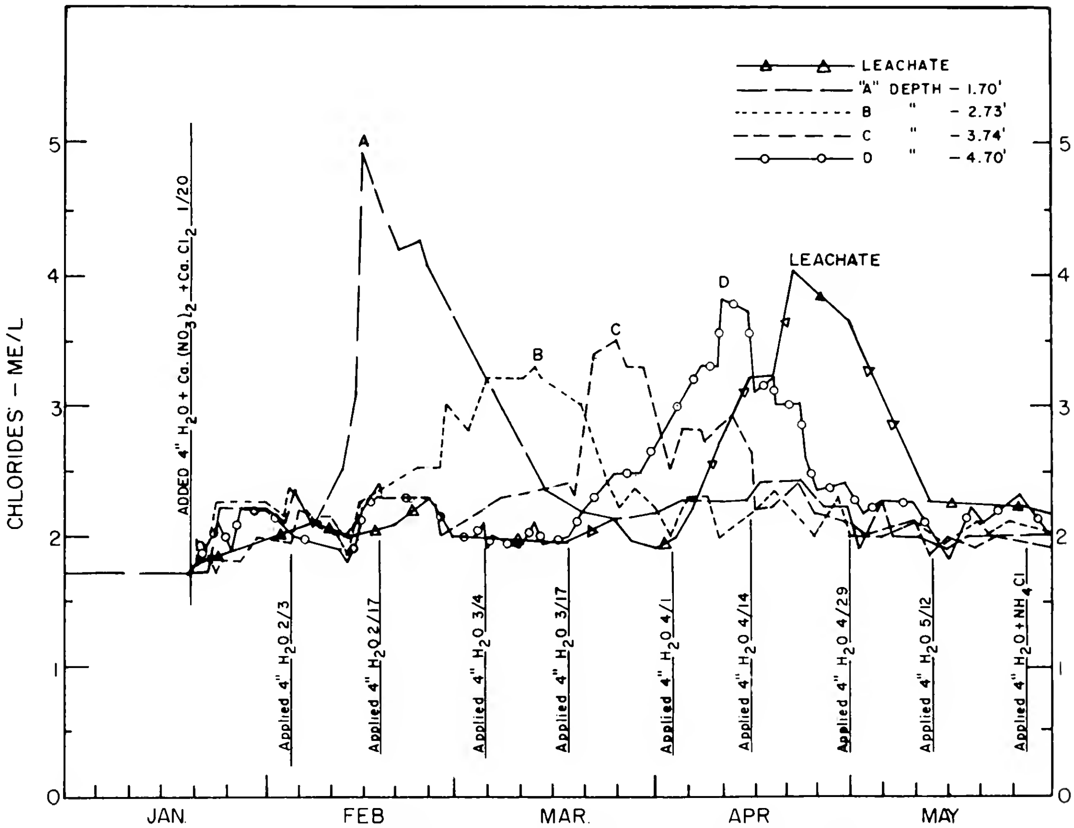

FIG. 18 - MOVEMENT OF CHLORIDES IN SOIL COLUMN

The losses were due to the removal of nitrogen by the crops, removal in the leachate, removal through sampling of the suction probes, and the unaccounted for losses to be primarily the result of denitrification and volatilization reactions. The amount removed by the barley and milo crops was 2.90 grams or the equivalent of 226 pounds per acre. A calculated 0.55 grams, the equivalent of 43 pounds per acre, was removed in the leachate and 0.12 grams, or 9 pounds per acre, was removed by the suction probes for sampling purposes. There was an unaccounted for loss of 14.6 percent of the applied fertilizer which was 0.15 grams or 12 pounds per acre. The causes of these losses were not documented but it is postulated that the major cause was denitrification and a minor cause was volatilization of nitrogen compounds. There were undoubtedly some similar losses from the other sources of nitrates but this was not proven, therefore, no values were assigned to them. The total losses of nitrogen from all factors amounted to 3.7 grams or an equivalent of 290 pounds per acre.

In addition to the losses, in order to balance the system, the nitrates that remained in the soil column at the end of the study must be accounted for. These were measured to be 0.55 grams or 43 pounds per acre. The losses plus these residual nitrates totaled 4.27 grams or 333 pounds per acre. This amount compared to the measured contributions of 2.42 grams or 190 pounds per acre gives a difference of 1.85 grams or 143 pounds per acre. It was assumed that mineralization of the organic nitrogen compounds in the soil was the major source of nitrates that made up this difference of 143 pounds per acre. This amount is somewhat larger that much of the data cited in the literature. It indicates the large reserve of potential nitrates that are in most soils in the insoluble organic forms.

The assumption was made for this study that nitrate -N is the only soluble nitrogen form in the soil and water. The measurements indicated that although there were small amounts of ammonia and nitrite the quantities would be insignificant in the overall balance.

A summary of the nitrogen balance is in Table 31.

Sources of Nitrogen to the Drain

The nitrogen that occurs in the drain effluent originates from three major sources: (1) those sources that are native to the area or occur naturally, (2) those that occur as a result of agricultural activities and (3) those that occur from municipal and industrial waste products.

The major source of native nitrogen to the drain will be that which occurs naturally in the soils and substrata or the soil profile. There may be small quantities of ammonia and nitrate present in the drainage water but for all practical purposes the nitrogen that

Table 31

Nitrogen Balance Sheet - Lysimeter #6

Item	Nitrogen	
Contribution	gms	lbs/AC
Residaul NO_3-N (start)	1.06	83
Applied Fertilizer Nitrogen	1.27	100
Applied in Water	.09	7
Mineralization	1.85	143
Total	4.27	333
Removal		
Crop (barley and milo)	2.90	226
Leachate	.55	43
Suction Probe	.12	9
Unaccounted for Losses	.15	12
Total	3.72	290
Residual NO_3-N (end)	.55	43
Total Removal & Residual	4.27	333

moves to the drain will be in the nitrate form. Nitrates are soluble and readily moved with the percolating waters. If they are not intercepted by the plant roots or reduced to a volatile gas,usually molecular nitrogen and/or nitrous oxide, they will eventually appear in the groundwater or drainage effluent. The ammonia in the soil is normally adsorbed by the soil base exchange mechanism and will not move with the water.

The largest quantity of nitrogen in the soils is in organic forms. Although these forms are generally inert, mineralization takes place through a three step process which converts organic N to nitrate by bacterial activity. The bacteria are obligate aerobes which require molecular oxygen to produce nitrates therefore maximum nitrification will take place in the plow zone of the soil. Nitrification will decrease with soil depth and in areas of high water table usually no nitrates will be formed. Studies indicate (19) that 40 to 80 pounds of nitrogen as nitrates may be produced each year in the top five feet of soil by this process.

Data from the transect study indicated that the average quantity of nitrate in the 0-5 foot depth of soil was 258 pounds per acre. The

rate that this nitrate will be moved to the drain is subject to much speculation. Under the most favorable conditions, that is complete piston flow displacement, within about five years nitrates in the top five feet of soil immediately above the drains would be leached. This estimate was based on a pore volume of six inches per foot or 2.5 feet for the five foot solid profile and the estimated drainage effluent of six inches per acre per year. However, from field experience and laboratory investigations, it is known that complete displacement does not occur. There is diffusion by the salts into the smaller pores where they are isolated from the percolating water moving through the larger pores. Also under cropped conditions evapotranspiration removes the moisture from the upper soils thereby creating a moisture gradient upward and reversing the direction of the water and salt movement.

Other factors that will influence the length of time it will take the nitrates to reach the drain are the drain spacing, the depth of the drain, depth of soil barrier, and the hydraulic conductivity of the soils.

Estimates of the nitrogen contributions of each of the various sources were developed in the section on the nitrogen budget analysis. The values are listed in Tables 1 through 7. The analyses show that on an overall basis the nitrogen added to the soil by fertilizers, irrigation water, rainfall, stream flow, leguminous plants, animal and municipal wastes were essentially in balance with the nitrogen removed by the harvested crops and volatilization of nitrogen gases. Regardless of the source of the nitrogen taken up by the plant, whether from sources outside the soil or from the residual nitrogen in the soil, the same amount of nitrogen would be available to be leached to the drains.

It is obvious that where the nitrogen contributions are not evenly distributed throughout the area, such as cattle, municipal and industrial wastes, only a small part of the nitrogen from these sources will be used by the crops. As a result a larger percentage of this nitrogen could be leached to the drains.

The beef cattle operations now are concentrated in three feed lots in an area of about 500 acres. Much of the waste from these lots will be removed as manure and spread throughout the district and a lesser amount will be lost by volatilization. The remainder could be a source of the nitrogen in the drainage water. The amount of nitrogen from this source that reaches the groundwater will vary with the conditions present, such as rainfall, soil conditions, and surface drainage. Although no specific studies were conducted in this area, other studies give some indications of the relative amounts of nitrate moving through soil profiles toward the groundwater. The contributions of nitrogen from concentrated livestock feeding operations were studied in the South Platte River Valley in Colorado (20). The average total nitrate-nitrogen to a depth of 20 feet in the soil

profile averaged 1,436 pounds per acre as determined from 47 core samples. There was a great variability in these samples, ranging from almost none to more than 5,000 pounds per acre. Also the water samples collected from under the feed lots had a greater concentration of ammonium -N than those sampled from irrigated croplands. The feedlot samples averaged about 4.5 ppm and the irrigated field samples averaged only about 0.2 ppm.

The rainfall in the area cited above is about double that of the San Luis area. Undoubtedly there would be less movement of nitrogen here but some areas near feed lots probably will have unusually high nitrogen concentrations in the drains.

In a like manner, the areas adjacent to the municipal sewage disposal systems would have large quantities of nitrate leached into a small area. The drains serving these areas would have unusually high nitrate concentrations in the effluent unless some remedial actions are taken to either transport them to other areas or install treatment processes to remove the nitrogen before it reaches the groundwater.

Quantity of Nitrates in the Drainage Effluent

The existing drains on the lands adjacent to the study area were monitored at various times by the State of California Department of Water Resources and the University of California at Los Angeles to determine the quantity and seasonal distribution of the nitrate concentration in the drainage effluent. In the San Luis area where no drains have been installed, the nitrate concentrations were calculated from the Prediction Model developed by the University of Arizona and the Bureau of Reclamation Engineering and Research Center.

The data from the drains monitored in the San Joaquin Valley indicated a range of NO_3-N in the effluents from 2 to 400 milligrams per liter (21). The annual flow weighted average of these drains measured during 1966-1969 period was 19.3 mg/l. During the period for which data are available, there was no evidence that there has been any significant reduction in the average annual nitrate concentrations in the drainage effluent.

Anticipated Changes in Nitrogen Sources

Fertilizer Usage

The usage of fertilizer is expected to increase in the future however the rate of the increase is subject to speculation. Interviews with Agricultural Extension Specialists indicate that they anticipate little increase in the per acre applications on the various crops in the foreseeable future. This prediction is based upon two major premises: (1) The rates now used appear to be an optimum balance between costs and economic return and (2) The present emphasis on

ecology and conservation will exert public pressure on the farming community to prevent increased use of commercial fertilizers.

There will be changes in the cropping pattern toward more intensive farming, the production of crops that require higher fertilizer application, more double cropping and the development of the areas which are now non-irrigated. These changes will increase the amount of fertilizer that will be applied under ultimate development from the 1968 average application of about 60 pounds per acre to an estimated 87 pounds per acre. For the total area this would amount to an increase from about 20,120 tons to 29,200 tons annually.

Future Crop Pattern

Before supplemental surface water was available, the farmers were forced to adjust their crop patterns to accommodate a deficient water supply. Generally, this was accomplished by planting low water requirement crops, winter crops and allowing some land to lay idle or undeveloped. As water from the San Luis Project becomes available, the operator will be able to grow the crops which are most economically feasible or that best fit his farming program.

The major change in the crop pattern is expected to be the reduction in the acreage of barley and increases in alfalfa seed, vegetables and deciduous fruits and nuts. There is also expected to be an increase in the number of acres double cropped. It is projected that the lands which have not been developed for irrigation or have been left idle will be prepared for cultivation and for the most part will be irrigated each year.

Cattle production is expected to increase about in proportion to the increase in the human population. This production will be, as it is now, primarily a feed lot operation. This type of operation will continue to concentrate the nitrogen waste in relatively small areas and create local hot spots which could introduce high nitrate concentration to the drains servicing these areas.

Sheep production in the area is based primarily in grazing off the crop residues. Barley stubble has been the major pasture source; however, with the more intensive farming practices anticipated in the future, the acreage of this crop will be cut drastically. As a result, it is expected that the number of sheep will drop correspondingly. The resultant total nitrogen waste from both sheep and cattle will probably not increase appreciably over present levels.

Leaching Native Nitrogen

As explained in an earlier section, theoretically, the soluble nitrogen could be leached from the top five feet of soils in a minimum of five years, however, in actual practice it would undoubtedly be much longer. Also it could take many years to move that nitrogen that has been leached down into the subsoil near the midpoint of the drain spacings to the drains. The time required will

depend primarily upon the drain spacing, the volume of leachate, the hydraulic conductivity of the soils, and the depth of the sweep of the flow lines. This leaching time might be reduced by decreasing the length and depth of the flow lines by decreasing the drain spacing and depth.

The study that monitored nutrients from tile drainage systems (21) found that nitrates are not removed at as fast a rate as chlorides. This would indicate that there is a continuous replacement of nitrates in the system. The source of this replacement could be the applied nitrogen, primarily fertilizer, or from the organic nitrogen in the soil. The analyses of the transect samples show that there is a very large reservoir of residual organic nitrogen, a portion of which under favorable environmental conditions can be mineralized to nitrates. The rate that this organic nitrogen will be mineralized will depend upon the amount of the material present in the soil, the C:N ratio and environmental factors such as amount of aeration, moisture and temperature. The water quality systems model being developed in connection with these studies are expected to give some insight on the rate and the change in quantity over time of the nitrate mineralization under the various conditions present in the area.

Increase in Municipal and Industrial Water

Some demographers predict (23) that this area will become absorbed in a megalopolis (a sprawling population belt in which once clearly defined urban areas tend to blend into each other) that will cover most of Central and Southern California. This may occur at some very distant time, but for the foreseeable future no extreme change from the present rural pattern of relatively large farm operations and small towns is anticipated.

The importation of an adequate irrigation water supply which will permit more intensive farming and the construction of the north-south interstate highway through the area will give some impetus to a population growth; however, this will be offset by the increased mechanization of farm work and the resultant reduced demand for farm laborers.

If it is assumed that the population growth of the area continues at the same rate as the past ten years, although nationally the rate is expected to decrease, the population is estimated to reach about 25,000 inhabitants by 2010.

The improved transportation facilities available as the result of construction of the interstate highway will attract a number of new and different industries into the area but it is anticipated that the industry of the area will continue to be agriculturally oriented. It is estimated that they will increase somewhat more rapidly than the total population because of the increased requirements for mechanized equipment and services as a result of the greater farm mechanization.

The increased population and industrial growth will about double the waste-nitrogen disposal requirement for the area to approximately 174 tons. This amount will be spread over about twice the area; therefore, the per acre application rate will remain about the same as the present 53 pounds per acre. The drainage effluent near the feedlots and population centers may be high in nitrates unless some corrective action is taken to remove them.

Control of Nitrogen at the Source

The principal means of controlling the quantity of nitrogen that reaches the drains is by reducing the amounts of applied nitrogen, primarily fertilizers, and native nitrogen that are leached through the soils. These sources can best be controlled by educational programs to advise and encourage the most efficient farming practices and by the installation of specially designed farm drain systems.

Farm Advisory Program

The lysimeter studies show that under normal soil conditions and good irrigation management practices, very little applied fertilizer nitrogen reached the drain. However, in actual farm practices where the soils, crop, root pattern and cultural practices vary greatly, a greater percentage of this applied nitrogen could possibly move to the drain.

An advisory program conducted by the Agricultural Extension Service and other agencies should be encouraged to advise growers on cultural practices that would reduce the amount of nitrogen that moves through the soil profile to the drains. The areas in which these agencies might give assistance to the farmers could include:

Soil Management: Although most of the soils in this area are medium to fine textured there are sizeable areas of light textured soils on the south end of the district. It is especially important that these light soils are managed properly to prevent excess leaching. Practices which could be encouraged to reduce losses might include matching of crops to soil conditions. Studies (20) have shown that fields of deep rooted crops such as alfalfa have practically no nitrates below them. An alfalfa crop in rotation with shallow rooted crops possibly would prevent much of the nitrate leached below the root zone of shallow rooted crops from reaching the water table.

Fertilizer Management: Some types of fertilizers, especially the nitrate forms, are fast release types which may be leached fairly rapidly through the soil. Other types such as ammonia forms which are absorbed by the negatively charged ions in the clay particles and specially treated urea forms which dissolve slowly in the soil are less rapidly leached. The effect of the rate of release on the amount of nitrogen leached would be especially significant in the light textured soils. Other factors which would

influence the rate of movement of the nitrate through the soils are the amount, time and placement of the fertilizer. Under conditions of rapid nitrogen movement it would be better to make a larger number of smaller fertilizer applications than one large application. Also there would be less losses if the fertilizers were placed in bands near the areas of greatest root density rather than being broadcast uniformly over the field.

Water Management: Nitrate -nitrogen generally will move with the percolating water. Irrigation applications should be adjusted to avoid excess deep percolation and the resultant loss of nitrogen. Only enough water should be applied to meet the evapo-transpiration requirements of the crops and have adequate deep percolation to prevent a buildup of salts in the root zone.

Crop Management: Various crops have different nitrogen requirements and, as mentioned above, different root depths which influence nitrogen utilization. The amount of nitrogen leached to the drains might be reduced by growing the high nitrogen requirement plants on the fine textured soils.

Specially Designed Farm Drain Systems

Once the residual or applied nitrogen has moved below the root zone of the plant, the only means to reduce the amount that will reach the drain is by denitrification or by reducing the area that contributes to the drain.

Laboratory studies (17) have shown that denitrification, the reduction of nitrates to nitrogen gas which is dissipated to the atmosphere, can take place in soils, therefore, under proper conditions it should occur in the field. The process normally takes place in the saturated soil near or at the water table as a result of the action of anaerobic bacteria. Willardson, et al (23) are conducting studies to determine if, when the drain lines are submerged continuously and an organic energy source present, there is a reduction in the nitrate concentration of the effluent. If these results prove positive, recommendations should be made that farm drains be designed to maintain submerged conditions to encourage denitrification.

The quantity of nitrates in the soils and substrata which can be leached to the drains is directly proportional to the depth of the area swept by the drainage flow lines. Any action which will reduce the depth of the flow line will reduce the ultimate quantities of nitrate in the drain. The most feasible methods to do this is to decrease the drain tile depths and spacings.

SECTION VI

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27 Abstract
A nitrogen balance study of the San Luis Service Area determined that the average annual nitrogen contributions from all sources other than residual soil nitrogen were approximately equal to the nitrogen removal by crops and gaseous losses. This would indicate that, although in many instances the residual-nitrates would replace some of the contributed nitrogen, especially fertilizers, animal and municipal wastes, the amount of nitrates moved to the drains would be proportional to the amounts of soluble, native nitrates in the soil.

A soil sampling study at several sites throughout the area indicated that there were a wide range in the concentrations of nitrates, ammonia and organic nitrogen in the soils and subsoil. There were extremely high concentrations of nitrates in those soils located on the interfan positions between the larger streams.

Fertilizer studies in lysimeters shows that in medium to heavy textured soils under normal irrigation and fertilizer management practices very little nitrogen is leached to the drains. Nitrate type fertilizer contributed more nitrogen to the drainage effluent than ammonia and slow release sulfur coated urea fertilizers.

It was concluded that the best possibilities to reduce nitrogen in drains by on farm practices will be to establish Farm Advisory Programs to encourage the most efficient farm management and fertilizer practices and to design drain systems to promote denitrification and reduce the area swept by the drain flow lines.

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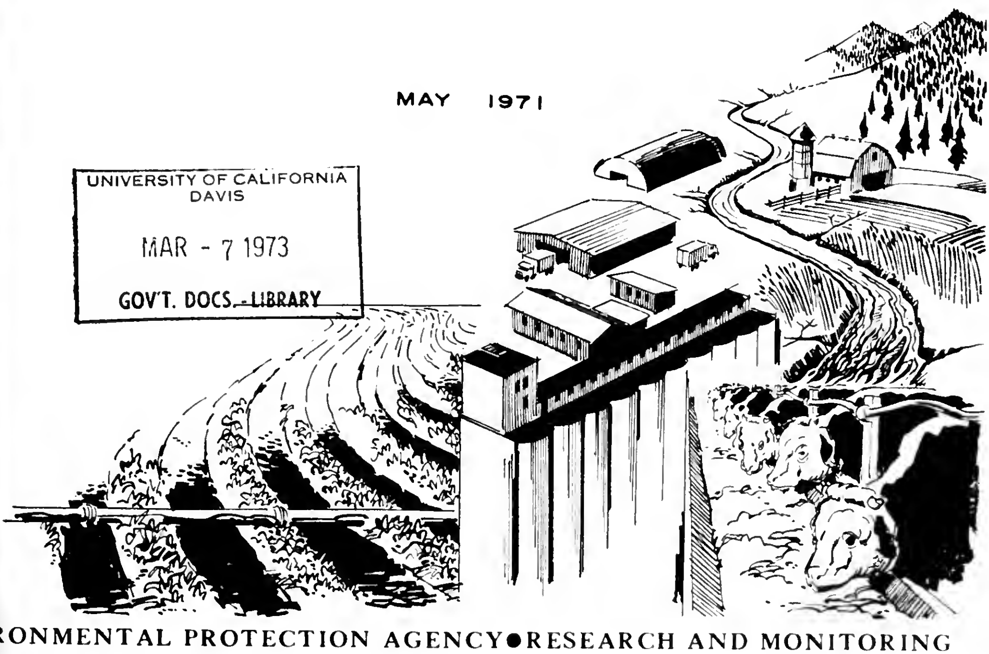

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